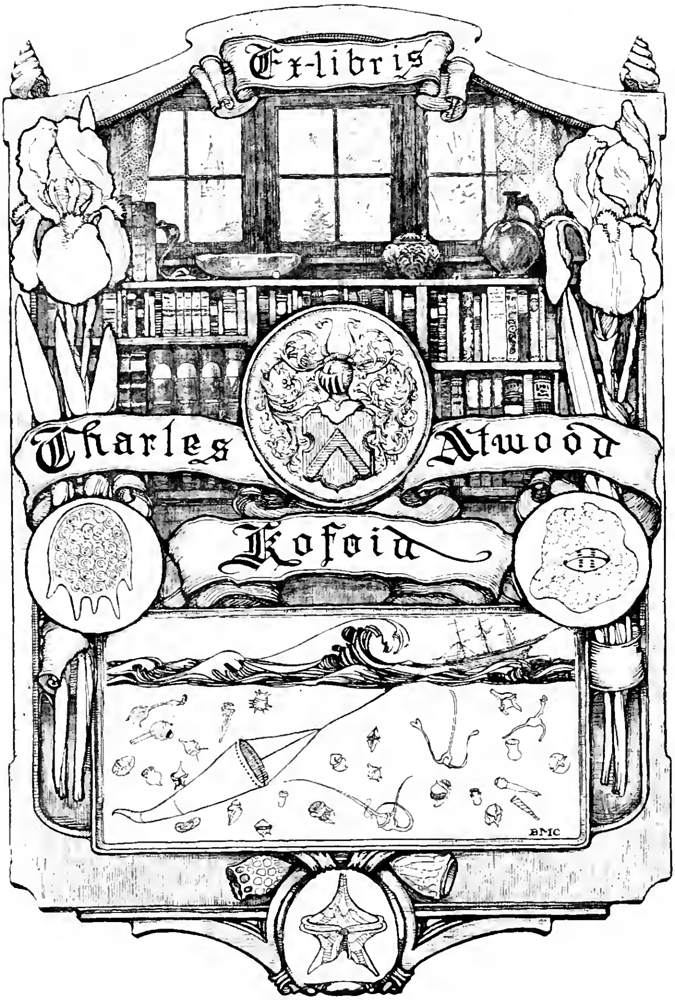
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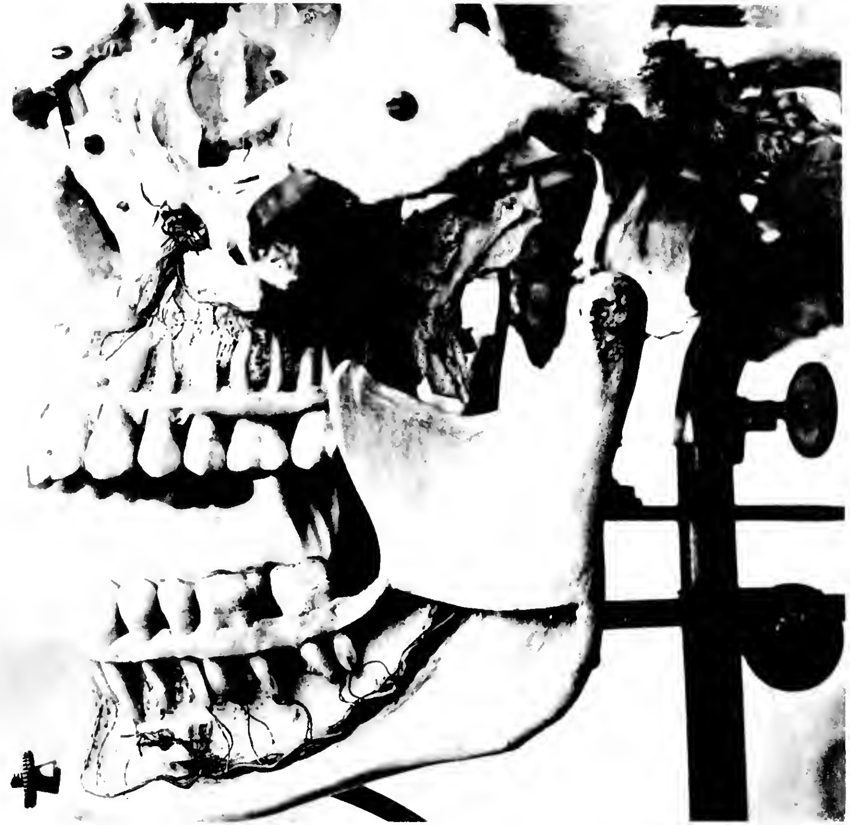

THE VASCULAR AND NERVOUS SYSTEMS

OF

THE MAXILLÆ AND MANDIBLE OF A CHILD. $\times \frac{1}{1}$

AN INTRODUCTION

TO

DENTAL ANATOMY

AND

PHYSIOLOGY

DESCRIPTIVE AND APPLIED

BY

ARTHUR HOPEWELL-SMITH

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WITH 340 NEW AND ORIGINAL ILLUSTRATIONS, INCLUDING A FRONTISPIECE IN PHOTOGRAVURE AND 5 PLATES

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PREFACE

An attempt has been made in the following pages to place before the reader a short account of the Essentials of Dental Anatomy and Physiology, and in consonance with the requirements of a utilitarian age, to indicate those aspects of such a subject which may have some direct practical bearing upon the science and art of Dental Surgery. Odontology is a matter of fundamental importance to one who has entered, or who is about to enter, upon the practice of this special branch of the treatment of disease. Hence it is important to decide what is necessary for the student to know, that he may be able to deal intelligently and intellectually with every phase of his adopted profession as he encounters it during his life's work.

A further endeavour has been made to endow an admittedly unattractive topic with some degree of interest, and to create in the mind of the reader an atmosphere of regard which the contemplation of the Anatomy of the Teeth deserves and demands. Surely even a halo of romance can be found, if looked for, in this study, so closely is it interwoven with the Natural History of Man and animals on this planet. Human teeth have been imperishable structures—when not affected by disease—from countless ages; and their physical characters and enduring natures have been, are, and may be able to render them of the greatest value in medico-legal cases in which much happens to be involved.

As an occasional means of identification of the illustrious dead, *e. g.*, Louis XVII of France, and the Prince Imperial, son of Napoleon III, killed by the Zulus in 1879, or the victims of great calamities, such as extensive fires, like that of the Bazar de la Charité in Paris in 1897, the teeth, when exhibiting the results of surgical interference, have been found to be of enormous importance; in criminal cases their similar silent testimony may prove or disprove a legal argument; in the remains of prehistoric man they afford a clue to the nature of the food which supported life in those far-distant ages; and in indicating the habits of the individual of whose body they form a part, they may reveal the higher qualities or the baser constitution of his mental attributes.

From a strictly scientific point of view, also, the modern zoölogist, appreciating the value and importance of the dental armaments of the vertebrates, has employed some of their main features for the purpose of classifying and arranging, in their proper positions in the scheme of Natural History, several orders of mammals, such as the rodents, the whales, and the marsupials.

Of Sir Richard Owen it is said that, given a single fossilized tooth, he could reconstruct, with considerable accuracy, the main skeletal features of its owner, whether bird, beast, or fish.

In short, teeth take their allotted place in Nature as do the other parts of the anatomy of Man, and on these grounds alone should be deemed worthy of consideration, attention, and investigation.

The mission of this book is to explain how it comes about that Man has a certain number of teeth, to describe their functions—combined, individual, component—to relate the method of their implantation, to detail their growth and the origin of the complexities of their patterns, and to narrate the *rôle* they play in the economy of Nature generally, and their close association with other portions of the body.

As on viewing a picture for the first time one stands, or should stand, at a distance, to apprehend its perspective, and inspect its composition in its entirety, and afterwards approaches closer to examine, in extended detail, its several portions, so should be the attitude of him who takes up this, or other similar volume. It should be quickly perused from cover to cover, until a general survey of the subject and the meaning of the arrangements of its parts is understood. Then each portion should be scrutinized, and studied *in extenso*.

The student would, therefore, be well advised to read the pages consecutively, not a passage here and a paragraph there. It has, of course, been expedient to divide the material into Chapters, but they have been harmonized in such a manner that each is dependent upon the preceding, and cannot possibly be thoroughly appreciated without a knowledge of the contents of its predecessor. Each chapter anticipates the next, and leads up to those treating of the Anatomy and the Relationships of the Teeth of Man, which, in the author's opinion are the most important of the whole series.

A knowledge of the elementary principles underlying the study of general anatomy, general physiology, and biology is presupposed and actually required; the corollary being, therefore, that this work is intended for the use of the senior student and practitioner. Certain chapters, such as those dealing with the homologies of the Teeth, the development of the mammalian crowns, the influence that the Darwinian theory of evolution has upon the teeth, as being of less importance than the others, have, purposely, been treated in sketchy outline. Descriptions of the minute anatomy of the dental and oral tissues have been designedly omitted; for information regarding them references should be made to the Author's "The Histology and Patho-histology of the Teeth and Associated Parts." Comparative palæontology has been likewise disregarded, as it is of but little moment in relation to the exercise of every-day dental work.

It would seem that a modification of some of the expressions commonly made

use of in dental parlance is imperative and necessary. In connection with the names of teeth, the "central" incisor should be invariably known as the "first" incisor, the "lateral" as the "second" incisor. Similarly the word "bicuspid" should be entirely replaced by "premolar," and it is at once obvious that the terms "six-year-old" molar, "twelve-year-old" molar and "wisdom" tooth are wrong. In conformity with the principles and teachings of Comparative Anatomy these teeth should be recognized as the "first," "second," and "third" molars. The "temporary" should always be styled the "deciduous" dentition; and the "articulation," the "occlusion" of the teeth. Further, it is evident that designations such as "open bite," "edge-to-edge bite," "underhung bite," are obsolete, and that it is desirable, as pointed out in Chapter XI, to change them to "opharmosis," "prosharmosis," and "epharmosis" respectively.

For the preparation of this work much information has been obtained from examinations of the specimens in the Natural History Section of the British Museum, the Odontological Collection of the Royal College of Surgeons of England, the Museums of the Royal Dental Hospital of London, Guy's Hospital, the Universities of Cambridge and Birmingham, the École Dentaire de Paris, the Anatomische Anstalt der Universität, Berlin, and the Pathologisches Museum der Kgl. Charité, Berlin.

The author has almost essayed "prendre la lune avec ses dents." If he has succeeded in his task of merely introducing some of the fascinating facts and theories of Dental Anatomy and Physiology to the younger generation of students, his attempt will be justified.

Portions of the book have already appeared substantially in the *Transactions of the Fifth International Dental Congress*, and the *Second Australian Dental Congress*.

In connection with the publication of the volume, the author owes an especial debt of gratitude to his eminent and learned friend, Dr. Edward C. Kirk, for his editorial services, so readily proffered and so willingly undertaken; and he desires to acknowledge his grateful thanks to the Publishers for the extreme care they have exercised with regard to the typography and the pictorial aspect of its pages.

To the writings of Mr. Chas. S. Tomes—whose "Manual of Dental Anatomy" is well-known—of Mr. E. Clodd, Dr. Black, etc., he is greatly indebted for very much inspiring and interesting intelligence. Many of the illustrations are from photographs taken by Mr. George Payne, Sub-Curator of the Museum of the Royal Dental Hospital of London, of specimens therein found, and also in that of the Royal College of Surgeons of England, and to him, and to the authorities of these latter institutions he is beholden for much kind help.

Park Street, Park Lane, London W.

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CHAPTER I

THE VALUE OF THE STUDY OF DENTAL ANATOMY

CORRIGENDA

Page 65, line 15, *for* "sixteen" *read* "twenty-four."
Page 131, line 4, *for* Fig. 76 *read* Fig. 77.
Page 131, line 7, *for* Fig. 77 *read* Fig. 76.
Page 143, line 20, *insert* "in" *after* "Mesonix."
Page 147, line 12, *for* "on" *read* "in."
Page 152, line 16, *for* Figs. 97 and 98, *read* Figs. 92 and 93.
Page 182, line 13, *for* "cornu" *read* "cornua."
Page 205, line 10, *for* "measurement" *read* "mensuration."
Page 211, line 26, *for* "surfaces resemble" *read* "surface resembles."
Page 226, line 21, *insert* "As a consequence of" *before* "attrition."
Page 230, line 22, *for* Fig. 239 *read* Fig. 238.
Page 246, line 9, *for* "foramen" *read* "pomum."
Page 253, line 2, *for* Fig. 194 *read* Fig. 99.
Page 290, line 3, *for* Fig. 240 *read* Fig. 241.
Page 316, line 6, *for* "Cantetidæ" *read* "Centetidæ."
Page 316, line 8, *for* "Solemodons" *read* "Solenodons."
Page 319, line 15, *for* "sub-orders" *read* "sections."
Page 325, line 5, *for* "canine" *read* "marine."
Page 331, line 26, *read* "Proboscidea includes Elephantidæ and Dinotheriidæ."
Page 332, line 2, *read* "Perissodactyla includes Equidæ, Tapiridæ, and Rhinocerotidæ."
Page 338, line 5, *for* "to" *read* "with."
Page 339, line 7, *for* Fig. 312 *read* Fig. 314.
Page 345, line 7, *for* "diplyodont" *read* "diphyodont."
Page 351, line 9, *for* "breach" *read* "breech."
Page 361, line 5, *for* "molar" *read* "premolar."

DENTAL ANATOMY AND PHYSIOLOGY

CHAPTER I

THE VALUE OF THE STUDY OF DENTAL ANATOMY

Introduction.—Dental Anatomy the Alphabet of Dental Surgery.—The Utility of a Knowledge of its Principles.—The Value of the Study of Comparative Dental Anatomy.—Problems associated with the Subject, and the Need for their Examination from Various Points of View.—Scheme of Succeeding Chapters, culminating in Human Dental Anatomy Proper.—Study completed by brief Accounts of Dentitions of the Order *Mammalia*.

INTRODUCTORY

On approaching the systematic study of Dental Anatomy and Physiology the work of the student who is about to commence his professional education is beset by many difficulties. He has, in present circumstances, but little leisure to devote to it. The pressure and stress of other parts of the curriculum, more invaluable to his mind, crowd out of his daily routine of reading, all but a mere glance at this fundamental basis of his dental knowledge, all but a mere trace of an acquaintance with the Alphabet which constitutes the beginning of his erudition. The subject is relegated to an inferior position in his category of studies, and it is only when he is nearing his final tests for examination, that he hurriedly attempts to assimilate the mere outlines of a fascinating and really important branch of natural science. Much less does he familiarize himself with it.

In a measure this is as it should be. During novitiate days he ought to absorb most assiduously those methods of operation and technique which will be of most help to him in future practice. The making of a practical man is of the first importance, but the making of a cultured, refined man, with an enlarged mental horizon, is equally important; and, of course, more time must be given to the pursuit of practical matters than is necessary for a complete grip of the science

of Dental Anatomy. A profound knowledge of it does not, *per se*, enable a dental surgeon to prepare and fill a carious cavity in a tooth in the most efficient manner possible. This is more or less a mechanical operation, and is performed by a rule-of-thumb method, a result of good training and extensive experience. But it does, undeniably, assist him to carry out his intentions with regard to the preparation of such a cavity, and to the saving of the tooth intelligently, and much better than if he was not conversant with the gross and minute anatomy of the tissues. He must know something—yea, everything he possibly can —of the structure of the vital organs with which he has to deal. For the dental armament of Man is part and parcel of himself. Teeth are in their own unique way—and he is apt to forget it—as much a portion of the anatomy of Man as are his two eyes or his two ears. And an ophthalmic or aural surgeon could certainly not be expected to know anything of the disease of these organs, if he had never attempted to study their macroscopical and microscopical characteristics.

THE ALPHABET OF DENTAL SURGERY AND PATHOLOGY

A knowledge of Dental Anatomy, therefore, is of the utmost moment to those students who are training for their life work of dental surgery. It is something that retains the equilibrium between things, relieving and even beautifying the dull monotony of the mere drudgery of dental mechanics and operations. It acts very frequently as a mental shower bath; the mind is refreshed by it as by a series of experiments in mental gymnastics. But, more than this, it is the very A B C of dentistry. It is impossible to be able to read without first learning all the letters of the alphabet, then correlating them into words, then grouping them into sentences, then uniting them with the products of intellectual action—of memory and of imagination.

And so it comes about that in the treatment of affections of the teeth, either individually or collectively, either from a prophylactic or a therapeutic point of view, enlightenment on this subject is essential. Without it an intelligent grasp of the problems of dental physiology and pathology is an absurd and illusive phantom and as unattainable as an *ignis fatuus*.

There is, in addition, a higher and still more cogent reason for the retention of Dental Anatomy in the synopses of our schools, and its inclusion in the subjects of the qualifying examination. Original scientific work in the future will have to be undertaken by the student of today, and tomorrow. If the chief facts and theories connected with the science of Dental Anatomy were not presented to him, and his attention directed thereto, progress would be retarded, the work of research would be impeded, and dental science would stagnate, except with regard to mere empirical and mechanical methods for the purposes of making money.

The main point then would seem to be, in connection with the academical training, a lack of time during the student's fulfilment of his curriculum in which he can devote himself to its study.

But another serious difficulty presents itself. In biology and zoölogy, scientists express themselves—they cannot do otherwise—by the use of certain terms to indicate what is meant, which are at first quite foreign to the ordinary conception of the student. Greek and Latin derivatives are largely used for this purpose, and one of the great stumbling blocks to a student's reading of text-books on Odontology is the use and signification of biological and other terms, which are quite new to him. The subject is not in itself so very vast, but the new unfamiliar terms scattered throughout it are very numerous.

It is the purpose of the teacher of Dental Anatomy to lighten the work of the undergraduate, to facilitate his studies, to simplify—as far as is consistent with one's principles—the complexities and subtleties of his reading, to introduce him to a new and even romantic field of Natural History, and to induce in his mind a permanent and enthralling enthusiasm for the very elements of his early experiences. It is argued by the critic—who is not only captious but illiterate and unscientific in addition—that these premises are correct as far as a knowledge of the teeth of Man go. To such an one it may be pointed out, however, that an acquaintance with the anatomy and physiology of the teeth of the Vertebrates generally becomes necessary for a proper understanding of many physiological as well as pathological problems, whether acquired or congenital. For much is to be learnt regarding the development and the morphological irregularities and defects

and deformities of the teeth of Man by observing and considering the comparative side of the question. Such a knowledge cannot help but throw an interesting side-light on many anomalous and diseased conditions seen in the human oral cavity.

SOME PROBLEMS

For instance: (1) The questions of the value and relative importance of the first permanent molar with regard to the saving or the extraction of this tooth is, or ought to be, governed by an exact comprehension of its early history as shown in the development of the molars of *Mammalia* generally; (2) a study of that condition known as hypoplasia of the enamel should be partially regulated by the observations which follow the experimental feeding of small mammals, such as mice or guinea-pigs, or rabbits, with meat, or vegetables, or artificial foods; (3) accuracy of interpretation of the structure and meaning of the presence of secondary or adventitious dentine in the dental pulp is helped by a histological survey of the dentines such as osteo-, vaso-, or plici-, as met with in fishes; and (4) finally (although it were easy to multiply examples) the more abstruse and recondite problems connected with the gradual loss of the teeth of Man—an incisor and a third molar—and the pathological conditions recognized as superior protrusion and circumdental diseases, should be associated with a considerable knowledge of the genesis, growth, and functions of the maxillary bones, and nasal fossæ on the one hand, and their occurrence in the lower animals on the other.

There is also another point to be remembered with regard to the consideration of the comparative anatomy of the teeth, in the fact that such a study enlarges a young man's scientific train of thought, and by bringing before him facts and fancies connected with the development and growth and uses of the dental apparatus of fishes, reptiles, and mammals, leads him to the earnest contemplation of the romances and histories of the fauna of the world as seen either from an ecological or artificial standpoint. The attentive consideration of the lives and doings of animals is surely a most alluring occupation.

The functions and uses of the teeth are very varied and very manifold. The competent observer, in reply to the enquiry, "What is the value of the teeth?" would undoubtedly explain that their main functions were concerned with the process of mastication. This is correct as far as it goes, but it does not go far enough. With regard to the teeth of Man, probably the highest function as well as the most complex, because of its dependence on the proper workings of the higher cerebral centres, that they possess, is the power of the production of speech; and the proper performance of the mechanism of this is dependent on the more or less efficient state of his dental organs.

The captious critic may affirm, on reading or hearing the above, that the ideas associated with them are not essential to a proper understanding and execution of his daily work. He is replete and contented with his provincial egoistic empiricism. By thinking thus, however, he debases his position as a dental surgeon and becomes of the nature of a charlatan. In fact, if a knowledge of Dental Anatomy is withdrawn from a man's mind, or he is prevented by various means, from obtaining it, at once a line is drawn around him, and he is cut off from the company of those whose knowledge is based on science, and whose work is carried out as the logical outcome of such non-empirical formulæ and doctrines.

Let it be granted that enquiries are seldom forthcoming by a discriminating person on these points; at all events it will be agreed that one ought to know the most rudimentary physiological processes connected with the teeth and mouth.

Let the reader consider for a moment, for instance, the problem of the causes of the eruption of the teeth, and let him recall the various theories which have gathered around it.[5] Of these, discussed at some length in Chapter XIV, the older are, in brief, as follow:

(1) Teeth erupt on account of the elongation of their roots;

(2) On account of the general interstitial growth of the alveolar bone;

(3) On account of the blood pressure in the pulp, and sub- and circumdental tissues;

(4) On account of the enamel being an epidermal structure or acting as a foreign body;

(5) On account of the contraction of the alveolar plates, and deposition of bone at the base of the crypts, and so on.

The observer will at once discover how a very elementary subject like this may be wrapped in obscurity. If, however, he surveys the problem from the standpoint of the naturalist, biologist, and zoölogist he will find his meditations illumined by considering the *modus operandi* which obtains in the mouths of reptiles, and the lower mammals, and come to the conclusion, as the writer has done, that, in spite of the ingenuity of many of the theories, there is only one real explanation which may be given to an enquiring individual, *i. e.*, that eruption is a normal physiological process, governed by the same forces which are acting on the other parts of the body.

One cannot say exactly what forces determine the growth of the nails, that regulate the height of the stature, that superintend the length or abundance of the hair, that cause the descent of the testes, but it may be believed that they are nothing more nor less than physiological processes of growth on the part of Nature, which cannot be reduced to purely mathematical formulæ or dogma. The phenomena of dental eruption are observed in the case of odontomes in the jaws, of teeth which make their way occasionally into the nasal fossæ (Fig. 1), through the cheek, or the facial surface of the superior maxilla, or the sigmoid notch of the mandible (Fig. 2), and of organs which erupt on the free surface of the low type of bone found in certain teratomata (ovarian "dermoid" cysts), Figs. 3 and 4; and conversely, the laws of eruption are occasionally found to have become suspended or greatly modified when teeth remain buried in the jaws in an incompleted or fully developed condition (Figs. 5, 6, and 47).

In this way, therefore, a subject such as this just mentioned should be viewed and discussed, not only from the standpoint of general anatomy and physiology, but from the vantage ground of pathology, and last, but not least important, of zoölogy.

In this connection another matter of fundamental interest might perhaps be alluded to, to demonstrate the utility of Comparative Dental Anatomy in clarifying debatable points. Many years ago the author[2] published an article "On Dentogeny"—the growth and method of formation of mammalian dentine. In his own opinion he

FIG. 1

A skull of an adult in which a tooth had erupted into the right nasal fossa. $\times \frac{4}{5}$.

FIG. 2

A tooth erupted into the sigmoid notch of the mandible. $\times \frac{9}{10}$.

then held, and still holds more securely than ever, the belief that certain cells of the dental pulp, viz., the odontoblasts, do not form dentine matrix, but are chiefly, if not wholly, concerned in acting as trophic agents to the dentine, and probably as sensation carriers or transmitters to the pulp (see Chapter XV).

FIG. 3

Three premolariform "teeth" in an ovarian teratoma. Side view. $\times \frac{11}{10}$. The original in the possession of Mr. Aslett Baldwin.

FIG. 4

Three premolariform "teeth" in an ovarian teratoma. Viewed from above. $\times \frac{11}{10}$. The original in the possession of Mr. Aslett Baldwin.

This statement or theory was not seriously challenged, and in some quarters is, today, accepted as the probable truth, the building up of the matrix being ascribed to small, round cells on the surface and in the substance of the pulp itself. The main argument advanced

FIG. 5

Radiograph of a horizontally placed, unerupted, maxillary canine.

FIG. 6

Radiograph of a similarly placed maxillary canine.

against the theory was that of Tomes, who wrote ("A Manual of Dental Anatomy," p. 173, 1889): "Comparative anatomy furnishes evidence against the acceptance of such a view, as many vasodentines which contain no tube system, and so no dentinal fibrils, are yet formed

apparently by the agency of a layer of cells, corresponding in most features with the odontoblasts of other creatures."

Thus sections of the dental pulp of Hake (*Merlucius vulgaris*), when examined microscopically *in situ*, under low powers, show at the periphery, numerous long bodies which cursorily appear to be homologous with mammalian odontoblasts. On higher magnification it is seen that they are non-nuclear, and that they are merely bundles of connective-tissue fibres arranged like the constituents of the *membrana eboris*, and are not structurally or functionally comparable to these cells.

Four years later, therefore, Tomes modified this statement, and remarked: "We have always been accustomed to say that they (the odontoblasts) formed the whole of the dentine; now we know that they do not" (*Journal of the British Dental Association*, vol. xiv, p. 474).

It is interesting to add that Walkhoff,[6] too, considers that the processes of the odontoblasts serve essentially for the nutrition of the dentine. And Korff[3] and Studnicka,[4] still more recently, independently endorse these views. Thus MM. Dieulafé and Herpin[1] write: "Les odontoblastes ne sécréteraient que les gaines de Neumann."

So it can be understood that, at first, comparative anatomy destroyed this theory, but on further examination, built it up again and established it on still surer foundations.

SCHEME OF SUCCEEDING CHAPTERS

The course of a person's study in dental anatomy must be regulated largely by local conditions. The subject is world-wide. From east to west it is taught in the dental schools of civilized countries. And in conclusion, the author ventures to offer in subsequent pages, what appears to him to be the best means to be adopted by which an intelligent and logically sequential, if necessarily brief, survey of the subject can be conveniently adapted to the needs of the already overcrowded dental curriculum.

In unfolding a new design to an artist, in opening up an undiscovered

territory to a would-be explorer, it is wise to argue "from the known to the unknown." It is futile to jumble together facts and statements, and allow the student to stumble through the mass, so that, peradventure, a few salient features may remain in his memory.

The functions of the teeth form an excellent introduction to the subject. Universal is the knowledge of the uses of the teeth for the purposes of speech and mastication, but it is not so generally known that the latter includes comminution and trituration of food, that some herbivorous animals, for instance, browse on leaves, while some graze, as the giraffe and sheep respectively. One would have thought that all elephants would have possessed similar teeth, but the coronal patterns of the Indian and African species vary greatly, on account of the widely different foods which they have to comminute. (See Fig. 61.)

By pointing out these things, a student's imagination is at once fired, and he begins to take an interest in his newly found knowledge. The highest point of study should be, naturally, the naked-eye anatomy, the histology, and the physiology of the teeth of Man. And in order to reach this point, the discussion on the functions of the teeth is suitably and profitably followed by the presentation to the student of the number of the teeth of fishes, reptiles, and mammals, the shapes of the teeth crowns, the reason why they should assume these various shapes, with illustrations on the "adaptive modification" of organs, natural and sexual selection, and a disquisition on evolution as set forth by Darwin and others. The way is then paved for the proper consideration of, perhaps, one of the most difficult of all dental anatomical studies—the homologies of the teeth and its bearing on the human dentitions. Then comes the purely Dental Anatomy of the teeth of the *Primates*, including Man, succeeded by the minute anatomy of the tissues, the histogenesis of the teeth, and modes of formation of the hard and soft tissues, with the growth of the jaws and the functions of the various parts. The climax to the study is reached by studying the changes that the jaws undergo in infancy, adult life, and old age.

The work is completed by brief glances at the dentitions of the other orders and families of mammals, beginning with the *Cheiroptera*, and finishing with the *Monotremata;* is supplemented and greatly helped

by the use of explanatory illustrations, is raised to a high level by the association of the ideas and theories, and facts set forth with the working of the daily experience of men, in dental surgery and pathology; and should remain permanently fixed in the heart of the student as a pleasant and profitable memory and source of great delight.

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CHAPTER II

THE TEETH AND THEIR FUNCTIONS

Introduction.—Definitions.—Kinds of Teeth.—General Major Functions.—Foods of Fishes, Reptiles, and Mammals.—The Food of Man in Europe, Asia, Africa, America, and Melanesia.—As Factors in Facial Development.—The Specific Major Functions of Speech, of Ornamentation, of Emotional Expression.—The Minor Functions of Prehension, of Sexual Warfare, of Transport and Locomotion, of Offence, of the Toilet, of Chiselling, of Protection from Injury, of Sifting Food, of the Production of Sounds, and of Attack.—Functionless Teeth.—Dental Substitutes.—Application of Nature to the Requirements of Art.

INTRODUCTION

Various attempts have been made to classify those organized bodies endowed with life and voluntary movements which are known as animals, from the time of Aristotle (B. C. 350), who divided them into red-blooded and white-blooded or ex-sanguineous creatures, to the present day. The names of Linnaeus, John Hunter, Lamarck, Cuvier, Grant, Lydekker, and Ray Lankester are prominent among the *savants* who have made Natural History a special study. It is thus evident that several classifications exist. None are strictly accurate: all are open to objection. For present purposes, however, it may be said that the Animal Kingdom may provisionally be divided into:

Sub-kingdom I. *Vertebrata*—Vertebrates.
- Class I. *Mammalia*—Mammals.
  - Sub-class I. *Prototheria, i. e.*, first or primitive mammals.
  - Sub-class II. *Eutheria, i. e.*, ordinary mammals.
- Class II. *Aves*—Birds.
- Class III. *Reptilia*—Reptiles.
- Class IV. *Amphibia*—Amphibians.
- Class V. *Pisces*—Fishes.
- Class VI. *Cyclostoma*—Lampreys and hag-fishes.
- Class VII. *Protochorda*.
- Class VIII. *Hemichorda*.

Sub-kingdom	II.	*Arthropoda*—Crustaceans and insects.
Sub-kingdom	III.	*Mollusca*—Oysters, snails, and whelks.
Sub-kingdom	IV.	*Brachiopoda*—Lampshells.
Sub-kingdom	V.	*Echinoderma*—Starfish.
Sub-kingdom	VI.	*Bryozoa* or *Polyzoa*—Moss animals.
Sub-kingdom	VII.	*Vermes*—Worms.
Sub-kingdom	VIII.	*Cœlentera*—Sponges, corals, etc.
Sub-kingdom	IX.	*Protozoa*—Animalculæ.

The following pages are concerned with the Dental Anatomy and Physiology of the *Vertebrata*, particularly of Class I, and less importantly of Classes III, V, and VI.

THE TEETH IN GENERAL

Definitions.—It is remarkable, but nevertheless true, that in spite of much anatomical and pathological knowledge of the teeth, it is impossible to give an accurate definition of them. John Hunter, the Father of Odontological Science, whose extraordinary and unique work "The Natural History of the Human Teeth" was published in 1771, did not define them. Owen[14] described them, in his "Odontography" (1840), as "Firm substances attached to the parietes of the beginning of the alimentary canal, adapted for seizing, lacerating, dividing, and triturating food, the chief agents in the mechanical part of the digestive function." This definition, appropriate at the time of Owen's writings (1840–70), fails today, as will be seen presently. A shorter description might read as follows: "Teeth are the hard bodies in the mouth, attached to the skeleton, but not forming part of it, developed from the dermis, or true skin; their functions primarily being the comminution of the food."

The definitions just given describe sufficiently succinctly the teeth as the student knows them; but, in the realms of comparative embryology and in general pathology, structures are found which correspond morphologically so closely to them that one is justified in calling them dental organs. Bland-Sutton[2] has noticed that sheep are particularly liable to an anomalous condition of the skin in the neighbourhood

of the ear (Fig. 7). Occasionally a fistulous opening is found near the base of the auricle, the surface of which is surmounted by a tooth, invariably of an incisor-like pattern. This circular orifice he believes to be an accessory mouth which is usually single, but at times it may be associated with a small mandible and tongue. He writes: "The cervical teeth and the associated structures are remnants of an attached or parasitic creature, and the cutaneous opening represents its mouth."

He has also found tooth-like bodies attached to the temporal bones of horses, and recorded 40 cases in which they were present.

FIG. 7

Outline drawing of the head of a hornless sheep, showing (at *X*) an incisiform tooth near the base of the auricle. (After Bland-Sutton.)

FIG. 8

A caniniform tooth developed in and attached to the wall of an ovarian teratomatous cyst. $\times \frac{1}{1}$.

There are two theories as to the cause of the presence of the teeth in this situation. Bland-Sutton considers that they are probably due to parasitism, as they are usually unilateral; but other writers believe them to be due to a developmental error, connected with the first branchial cleft. In this case involution of the teeth-bearing part of the palato-pterygoid division of the first branchial arch would have occurred.

Interesting as these are from a comparative point of view, perhaps even more instructive still are the dental bodies found in certain embryomatous cysts, the so-called ovarian "dermoid" cysts. These

morphologically correspond to premolars and, more rarely, incisors or canines, being usually attached to a degenerated bone which is homologous with the alveolar process of the jaws, or occasionally to the soft tissues of the wall of the teratomatous cyst.[3]

Bland-Sutton gives an illustration in his "Tumors, Innocent and Malignant," of a "dermoid" cyst containing hair and "teeth," which was situated behind the rectum; also another of a dermoid found in the left naso-facial sulcus which possessed a "tooth." Other anomalous positions of "teeth," further, observed by this author, occurred in a congenital embryoma of the testis of a Chinese boy, which can be seen in the Museum of the Royal College of Surgeons of England, where it is shown presenting "the usual sebaceous matter, loose hair, and an embryonic rudiment consisting of bone, hyaline cartilage, and a multi-cuspidate tooth;" and also in the undescended testes of horses, which, "like typical ovarian dermoids, contain an ill-developed embryonic rudiment contained in a cyst, covered with pilose skin and stuffed with loose hair, grease, and occasionally teeth resembling equine incisors." These latter occurring in males are probably produced by hermaphroditic impregnation.[21]

The upper tusks of the male Malay wild boar (see Fig. 28) are placed entirely extra-orally.

Hence it is obvious that the definitions just given do not scientifically represent the term "teeth."

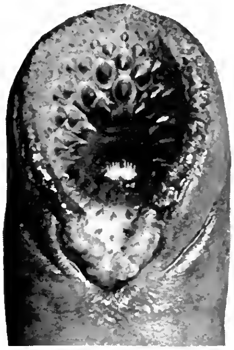
Kinds of Teeth.—Among the Vertebrates there are two kinds of Teeth: (1) Corneous; and (2) Calcified.

Comparative Dental Anatomy has little to do with the former, though in the Mammalian Order of the Monotremes, the *Ornithorhynchus* and the *Echidna* possess horny plates, which perform the functions of the teeth. Amongst the *Cyclostomata*,* the mouth of the lamprey is beset with corneous triangular or multicuspidate bodies, developed, no doubt, from an epithelial layer of cells, which go no further than forming a tough keratinous substance (Fig. 9). In the myxine there is one corneous tooth on the palate, superposed over a

* The *Cyclostoma* (Κύκλιος = round, στόμα = mouth) comprise Class VI of the *Vertebrata*, and thus form a class distinct from, and more lowly organized than the fishes, inasmuch as they possess no jaws, have a single—not a double—nasal aperture, and a rasping tongue.

horn-forming epithelium, which has, on its under surface, a small amount of enamel and dentine.[24]

FIG. 9

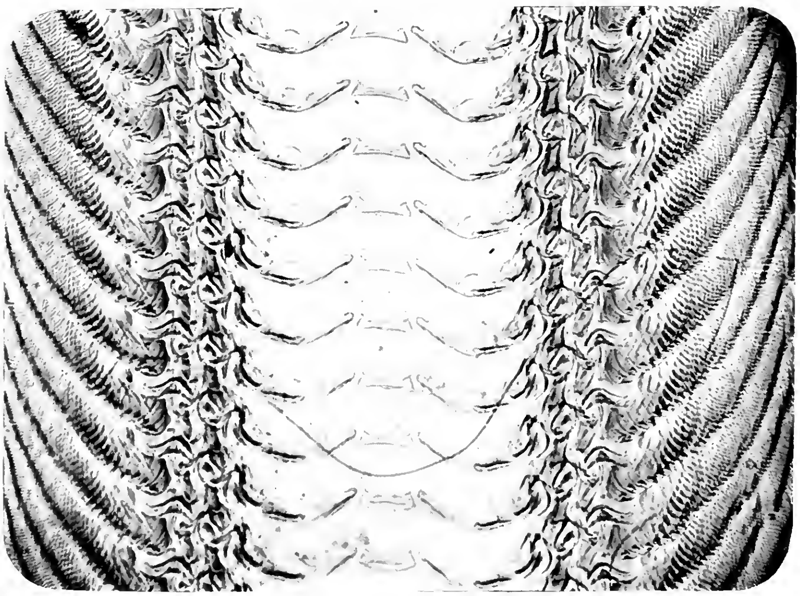


Head and mouth of a sea lamprey. $\times \frac{1}{1}$.

It is unnecessary to point out that the birds of today do not possess a dental armament. It is interesting, however, to note that the penguin's tongue is beset with long corneous papillæ whose function is identical with that of the lingual teeth of many fishes. This is well described in Brooke Nicholls'[3] "The Teeth of the Australian Animals."

Some *Mollusca*, like the whelk and snail, have *radulæ* in their mouths which are covered with minute teeth. There may be as many as three hundred in some species. Viewed under the microscope, either by transmitted light or with the help of the polariscope, they make beautiful objects (Figs. 10 and 11).

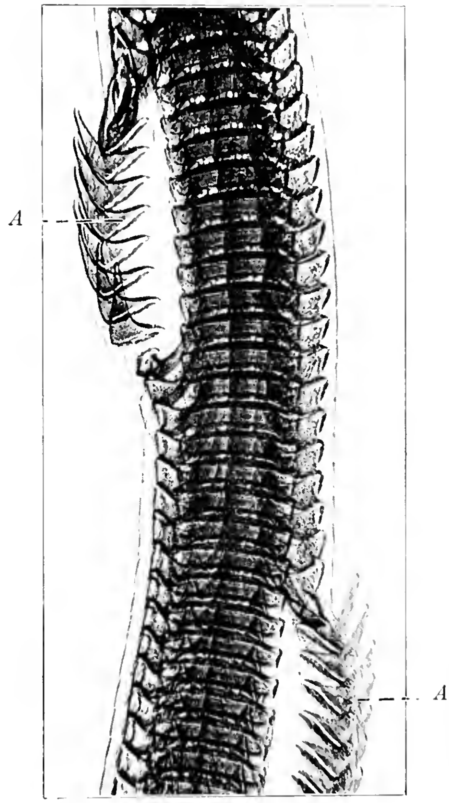
FIG. 10



Palate of a marine gasteropod (*Haliotis*), showing an axial part covered with a few, large, straight-edged teeth, an intermediate part with large serrated teeth, and an external part covered with many rows of sharp, pointed teeth. $\times \frac{120}{1}$.

In order to grasp the subject of Dental Anatomy, which includes studies in biology, zoölogy, ethnology, and anthropology, as well as general anatomy and palæontology, it is best to argue from the known to the unknown. The reader knows something about the functions of his own teeth. This, therefore, seems to be an excellent starting point for an excursion into this little-explored territory.

Fig. 11



Radula (tongue or lingual ribbon) of a marine mollusc, to show the numerous sharp, pointed teeth. At *A* seven teeth have become detached. $\times \frac{120}{1}$.

THE FUNCTIONS OF THE TEETH

The functions of the teeth considered collectively may be divided into two classes, Major and Minor, and the former further subdivided into General and Specific.

General Functions

Of the former, the comminution of food is universal. It will be noticed that the word "comminution" is used instead of the word "mastication," for it indicates more than is implied in mere mastication—it denotes the preparation of the food for assimilation by the digestive tract, by its reduction to small particles before its passage into the œsophagus.

The lives of fishes, reptiles, and mammals depend upon the proper assimilation of their food. Its preparation depends upon the functions of their teeth. All mature living creatures can feed themselves, and all possess organs which have masticatory powers, whose uses

are very diversified with regard to the various kinds of food which they comminute. The Amazonian ant, *Polyergus*, is, with one exception, the only instance of a living creature which has lost its natural instinct of *feeding itself*.[13]

The Foods of the Vertebrates.—FISHES.—The food of Fishes is extremely varied. It consists of aquatic plants and living creatures. Thus some members of the carp order (*Physostomi*), subsist on marine vegetable substances which require efficient mastication, a work accomplished by the *pharyngeal bones;* some are flesh feeders, and

FIG. 12

Jaws of wolf-fish (*Anarrhicas lupus*). Side view. $\times \frac{1}{5}$.

others live on the protozoa and small animals found in abundance in shallow pools. The herring feeds on small crustaceans like water fleas, 60,000 of which, according to Schmeil,[19] may constitute a meal; and the lamprey scrapes off the skins of fishes and then sucks up the blood and other body juices and soft parts. The shells of molluscs are largely eaten by such creatures as the plaice, the wolf-fish (*Anarrhichas lupus*) (Fig. 12), etc., while small fishes, insect larvæ, and marine worms fall victims to the sturgeon. The carrion of the sea and the kitchen refuse of ships provide food for the shark.

Reptiles.—Among the Reptiles, lizards eat butterflies, beetles, crickets, insect larvæ, flies, spiders, earthworms, etc. Snakes devour amphibians and their larvæ and fish. Vipers eat mice; crocodiles principally fish; and tortoises fish, amphibians, worms, and insects.

Mammals.—The food of Mammals is of a most mixed and extensive character. Thus, there are fruit eaters, as the apes, who also utilize for the same purpose young leaves and buds; the carnivorous animals, such as cats, etc.; the vegetable feeders, such as the deer; the fish eaters, such as the seals; and the omnivorous animals, such as Man, the pig, the wild boar, bear, etc. Bats are fruit and insect feeders; rodents—gnawing animals—subsist on vegetable substances, including those found in forests, *viz.*, nuts, beechnuts, acorns, etc. The elephant is herbivorous—but the African and the Indian varieties consume different kinds of vegetable matter. The whale is carnivorous, *e. g.*, the Greenland whale by means of its whalebone plates living on myriads of small but highly nutritious crustaceans and pteropods. Among the animals inhabiting the Australian continent the kangaroo eats grass, the duck-billed platypus molluscs, water plants, worms, etc.

The Food of Man.—As the comminution of food constitutes the most universal function of the teeth, it will be profitable to take a momentary glance at the constitution of the dietaries of mankind, which probably play such an important part in the incidence of dental caries. Although, generally speaking, there is no deviation from the standard patterns and types of human teeth, the races of the world, living in varying environments, eat different kinds of food.

A brief summary of these national diets may be given.

European.—(1) *Belgium.*—The principal articles of food are great quantities of fat, in the form of butter, lard, and "margarine."

(2) *Denmark.*—The staple diet is similar to that of the British Isles, but it comprises less meat and vegetables, more potatoes, rice, and other starch-containing bodies.

(3) *Greece.*—The poorest of the people mainly eat vegetables in summer and legumes in winter, all mixed with olive oil; the richer classes, meat cooked in butter. Fish is consumed

on the sea border. Bread and butter are practically never eaten, and pork but little.

(4) *Iceland.*—Fatty foods (butter and suet) are universal, and, on account of the intense cold, more indulged in than in any other country. Potatoes are used extremely largely; of other vegetables practically none. Beef, mutton, fish, black bread, and bread-stuffs generally are staple articles of diet. The use of coffee is general, but that of tea is rare, while that of intoxicating drinks is less frequent than elsewhere.

(5) *Italy.*—Meat and fat are very little eaten, except the latter in the form of oil. Maize, known as *polenta*, constitutes the main feature of the Italian regimen.

(6) *The Netherlands.*—Bread and potatoes are partaken of largely, as also are great varieties of vegetables and albumens and fats amongst the higher classes.

(7) *Roumania.*—The peasants, according to Lucas Championnière, eat vegetables; town dwellers an animal diet.

(8) *Spain.*—The poor man's chief sustenance consists of a thin decoction of innutritious meat, rice, bread, and water boiled up day after day with occasional additions, according to Bryden Hendinning, of "that which fortune may send and of garbage." The well-to-do classes adopt a French cuisine.

(9) *Sweden.*—In winter, potatoes are the only vegetable. It has been computed that the amount of meat averages 28 kilogrammes per head, milk, 183 litres, and butter, 5½ kilogrammes. Rye is used more generally than wheat. Smoked, salted, and dried animal food is eaten as a relish with butter and hard bread.

ASIATIC.—(1) *China.*—The poor have no meat. Rice is universally consumed, one to three bowlfuls being eaten at each meal, with salted beans, fish, or turnips as relishes. Occasionally, fresh pork or mutton is procured. Sugar is found on the tables of the rich and at feasts, but otherwise is little used, while edible birds' nests are frequently eaten. According to the *Scientific American*, in the year 1909, the weight of the edible birds' nests collected in the islands about Siam and the Malay

Archipelago amounted to eighteen thousand pounds, valued at about £20,000. The taking of the nests is fully described. It is stated that the birds require three months to build the first nests, which are gathered before any eggs are laid. Thirty days are occupied in building a second, which is taken in a similar way. The third nest is left, but after the young are reared, it is also taken and sold. After washing in cold water, the nests are cooked for eight hours. Various views as to the exact nature of the nest used in making the famous Chinese delicacy, bird's-nest soup, have been held. According to the above article it is now known that they are formed of a species of seaweed gathered by the birds. Unfortunately no authority is given for the statement. In Professor Newton's article in the "Encyclopædia Britannica" it is stated that they are made of a sort of mucus secreted by the salivary glands of the birds themselves. The builders of the nests are species of swifts belonging to the genus known to ornithologists as *Collocalia.* In the English swift the salivary glands are largely developed, and the secretion is used to glue together the materials of the nest. But in the *Collocalia* it forms "almost the whole substance of the structure." "This view," says Professor Newton, "has been needlessly doubted in favour of the popular belief that they were made of some sort of seaweed." This is supported by reference to analysis of the nest made by Mr. J. R. Green. On the other hand, Landor, who observed the birds in the Philippine Islands, says that they use the gum from certain trees for their nests.

The Chinese suffer from insufficiency of mastication, with all its attendant evils.

(2) *India.*—In the Punjaub sour milk is an article of diet with the morning meal. The Jains are strict vegetarians. Sir George Birdwood writes: "The Hindus eat an inordinate quantity of sugar, and some of their castes also of curry, and other scorching savouries, as also of all sorts of corrosive pickles, than which nothing can be more destructive of teeth. The true causes of their having fine teeth are, among others: (1) Their

habit of cleaning them with the yielding soft twigs of certain sacred trees; (2) and of chewing 'betelnut' (*Areca catechu*), with 'betel-leaf' (*Piper betel*) (this habit originating in the primitive typological rite of reddening or blackening the teeth, and drilling holes in, or knocking out one or two of them, on the young men and maidens of a community becoming marriageable, and still prevailing among the Aborigines of the Indian Archipelago), this habit, in the case of vegetarians, like the Hindus, serving not only to mitigate the flatulence of their diet, but strongly to consolidate their gums; and (3) above all to the universal Oriental habit, imperative among Hindus, of having their children submitted before marriage to the most anxious physical inspection, particularly of the teeth and nails (teeth being 'doublets' of nails, as the upper and lower jaws are of the arms and legs, and the head of the whole trunk). They regard fine teeth and nails as the most convincing credentials of a sound and vigorous constitution, and the happiest guarantees of male descendants. Their sound teeth are the result of at least 3000 years' practice of these religious rites."

(3) *Persia.*—According to Dr. Neligan, the Persian is a gross feeder, and his diet is simple and soft. Fat is largely eaten by all classes. The food eaten in Teheran is much the same as in the provinces, but is not of such good quality. The richer natives (Persians and Armenians) also consume European dishes, tinned meats, etc. The Persian takes a large quantity at a sitting and bolts it; he has practically only two meals in the day, one at midday, the other just before bedtime. Wholemeal bread is the staple article of food; meat and rice, "*chillau*" and "*pillau*," are eaten largely by the richer classes only; large quantities of fruit are partaken of in the season, especially melons, grapes, pomegranates, and dates. The most popular vegetables are lettuce, cucumber, and beetroot; cheese made from goats' milk is largely consumed. In the spring, Persians of all classes drink large quantities of curdled milk, of buttermilk, and of sherbert made of the juices of fruits with iced

water. Everything cooked is drowned in fat "roghan;" it is a form of "ghee," or clarified butter, made from sheep's and goats' milk, and varies in quality, but that generally used is very offensive in smell, taste, and appearance. The meat eaten is almost entirely mutton of poor quality. For those who cannot get meat, a broth made by simmering lumps of meat and fat in water for many hours is used. Animal fat is also indulged in, in large quantities, by the richer classes, in the form of "kabobs," which consists of alternate cubes of meat and fat grilled on a skewer over a brazier. The Persian stomach delights in bitter and acid things; its owner cooks all sorts of bitter plums, fruits, and herbs with his food. Tea is freely drunk; it is taken very weak; also a native spirit called "arak."

(4) *Ceylon.*—The Veddas of Ceylon (the aboriginal inhabitants), who live amongst the forests, "subsist chiefly on roots, fish, honey, iguana lizards, and the products of the chase, such as the Wadura monkey, the deer, and the wild boar. In their choice of food they are omnivorous, no carrion or even vermin being too repulsive to suit their appetite; and grain and fruits, when procurable, are used. Being skilful archers, they bring down, with their long arrows, such prey as bats, crows, owls, and kites, but for some curious reason they will not touch the bear, the elephant, or the buffalo. . . . Their food is always cooked. . . . They never wash, thinking it would weaken them, and they never laugh."[22]

(5) *Arabia.*—The peoples of Arabia have, as food-stuffs, wheat, maize, and barley. The date is the staple article of commerce, and their chief food. Coffee is largely drunk.

AFRICAN.—(1) *Abyssinia.*—Beef in a warm, raw condition at certain periods of the year is used. Mutton, chicken, etc., and leguminous vegetables are mixed with red pepper, together with various spices and a large amount of melted butter, the sole fatty constituent of the diet. The staple article of food is a small grain cereal known as "teff," chiefly composed of carbohydrates, with a small admixture of proteid material. Hydrocarbons are absent.

(2) *Bushmen.*—The Bushmen live on game, which they kill by poisoning. With the exception of goat flesh, they eat anything that is edible. When large game is wanting, their diet consists of locusts, the bodies and eggs of termites (white ants), wild beans, and roots. Putrid meat is partaken of with impunity.

(3) *Egypt.*—Bread, uncooked vegetables, beans cooked in oil, cheese, and goats' soured milk enter largely into the dietary of the people, while meat is partaken of only sparingly.

(4) The *Malagasi* live on rice; (5) the *Kaffirs* chiefly on milk, maize, millet, and yams. Cereals and tubers form the chief food of (6) the *Negroes*, some tribes living entirely on bananas, plantains, and cocoanuts. Certain pastoral tribes who eat meat and drink milk are prohibited for religious reasons from using vegetables. Fish is an important article of diet on the banks of the great African rivers. Cannibalism is still practised among certain of the African Negro races, and among the Negroes of the western parts of British New Guinea. Human flesh, used as food, is occasionally indulged in in the region of the Congo. It is not safe to visit some of the native villages unless properly guarded and well armed.

AMERICAN.—(1) The *Eskimos* (Eskimaux derived from *Wiyaskimowok, i. e.*, raw flesh eaters), in their savage condition, subsist almost entirely on animal substances. At times they eat roots, berries, and reindeer moss and seaweeds. In Danish Greenland a certain amount of imported food, *viz.*, bread, barley, and peas, is consumed. When food is abundant the Eskimo will eat as much as ten pounds of meat and fat at a single meal. Frozen flesh is devoured raw; fresh meat is boiled. The blood and contents of the stomach of the reindeer are added as articles of diet. Blubber too is valuable as a food, being used as fuel and lamp oil during the long winter months. The natives of the interior of Alaska eat fish, ptarmigan, susliks (or gophers or chipmunks), reindeer, sea lion, harp seal, and whale—commonly the white whale or *Beluga* of the Arctic seas—and occasionally a stranded rorqual.

(2) The *Fuegians* live almost exclusively on a shell-fish diet. Darwin[6] has noted that their staple food was a fungus (*Cyttaria Darwinii*).

(3) The *North American Indians*, such as the Sioux, formerly used the flesh of the bison as food, the skin being converted into clothing and other necessaries of life.

(4) Among the *Patagonians*, in the absence of farinaceous food, marrow and fat form the essential articles of diet. Blood is on all occasions eagerly drunk. Horse flesh is considered a luxury, and used on ceremonial occasions.

(5) The *Indians of Mexico* seldom employ condiments for flavouring food, which is generally simple in character and taken cold. The magnificent character of the teeth common to their race is undoubtedly due, as pointed out by Falero (*Dental Cosmos*, vol. xlvii, No. 5), to the fact that teeth and jaws only are used in eating food. Their "teeth are real knives, with which he (the Indian) cuts meat, peels sugar-cane, cuts string, or picks bones; of his molars we can say that they are true mills which pulverize everything that comes within their reach."

MELANESIAN.—(1) *Fijians* are large meat eaters, but they also consume many vegetable materials, such as taro, yams, sugar-cane, cocoanuts, etc.

(2) The *Maoris* eat, as staple foods, the sweet potato, fern roots, taro, breads made from the bulrush and from the berries of trees, edible seaweed, fish, and birds. Certain gums and bitumen are freely chewed. As Pickerill[16] remarks: "I have been unable to gather any evidence either from the Maoris themselves or from other observers that they ever practised cleaning the teeth by any artificial means."

(3) *Papuans* are largely vegetarian in their diet, but are partial to the flesh of pig, wallaby, and a large tropical beetle which is usually eaten raw. With regard to the so-called cannibalism which is found in New Guinea, a recent explorer, Dr. Lorenz, declares that the Papuans do not feed on human flesh, but there exist certain tribal ceremonies at which the heart and

brains of their dead enemies are consumed in order that the eater may secure for himself the courage and intellect of his slain foe.

The nature of the food of Man is an important factor to take into consideration when dealing with the problems of the etiology of dental caries. According to Pickerill,[16] "a large consumption of meat does not confer even a relative immunity." The following table, compiled from the interesting information given in his "The Prevention of Dental Caries and Oral Sepsis," shows, at a glance, the average incidence of caries in the relatively immune races of Mankind.

Maoris	1.2%	Kaffirs	14.2%
Eskimos	1.4%	Bushmen	20.6%
Northwest American Indians (coast tribes)	3.9%	Australian Aborigines	20.5%
Polynesians	5.2 to 19%	Tasmanian Aborigines	27.0%

As Factors in Facial Development.—It is highly probable that the development and growth of the jaws are governed by the important collective functions of both the deciduous teeth and their successors, which, according as they are well or ill placed in their respective arches, are able to impart to the face an aspect of refinement or animalism, as the case may be. A study of this question is, however, wanting, and definite statements cannot yet be made as to their precise rôle in this respect.

The Specific Major Functions of the Teeth

Speech.—Of the Specific Major Functions of the Teeth, the highest is speech—correct articulate speech,[25] the enunciation of words.

Salter[18] writes: "The teeth constitute an essential element in the organs of speech. Without them the precise and clear pronunciation of a great many letters, particularly consonants, would be impossible, and the resources of the oral cavity, as an organ of speech greatly circumscribed. Accordingly we find that when the teeth are lost, certain imperfections in articulation are immediately entailed.

"The principal way in which the teeth assist in the production of articulate sounds is by acting as an arch, or horse-shoe-shaped ridge, within which, and against which, the tongue may act as a valve, and by

pressing against which, it may produce a modified and variously placed partial or complete closure." The site of the sound is not when the tongue is in actual contact with the teeth, but when it is not in perfect apposition. Salter has constructed the following physiological alphabet:

Articulate sounds

Consonants

Vowels

a . . . . . . terminally dental
e . . . . . . wholly dental
i . . . . . . terminally dental
o . . . . . . not dental
u . . . . . . inceptively dental

Mutes (closure complete)

Soft	*Aspirate*
b . . . . . . labial	*p* . . . . . . labial
d . . . . . . dental	*t* . . . . . . dental
g . . . . . . (hard) palatal	*k* . . . . . . palatal

Semivowels (closure incomplete)

Nasal

m . . . . . . labio-nasal
n . . . . . . dento-nasal
ng . . . . . palato-nasal

Oral

Aspirate	*Soft*
f . . . . denti-labial	*v* . . . . denti-labial
s . . . . dental	*z* . . . . dental
rh . . . . dental	*r* . . . . dental
ll . . . . dental	*l* . . . . dental
ch (English) . . . . dental	*j* . . . . dental
th (in *through*) . . dental	*th* (in *thou*) . . . . dental
sh . . . . dental	*zh* (French j) . . . dental
ch (German) . . . palatal	

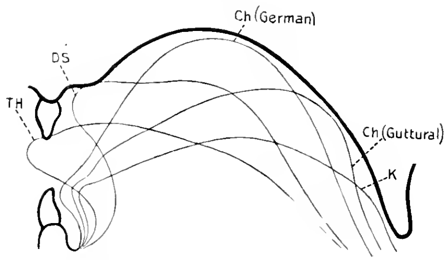
The accompanying diagram, after Salter, is intended to represent a sagittal section of the vault of the hard palate, the soft palate, and the tongue, and to show that the sounds of various letters are produced intra-orally by the positions of tongue, teeth, and palate. Thus the sound of the letter *K* is produced by the application of the back of the tongue to the soft palate and back teeth; *S* is formed on placing the tip of the tongue close against the gum behind the maxillary incisors, and *Th*, by carrying it further forward against the edge of the incisors themselves and projecting it slightly between the teeth.

The pronunciation of *D* involves the firm placing of the tip of the tongue against the gum behind the maxillary incisors, its edges against the lateral alveolar arches and teeth. Complete closure ensues, and

the letter is formed when the parts are suddenly separated. More forced breathing similarly produces *T*. In *N* exactly the same obtains, but the sound is continued through the nasal passages. When a person is suffering from nasal catarrh which somewhat occludes the nose, the pronunciation of *N* is as if it were sounded *ED*. In cleft palate extending through the soft tissues and the uvula, *D* cannot be sounded at all for this reason.

In the letters *F* and *V* the lower lip is brought into contact with the upper teeth, the former by a gentle, the latter by a forcible expiration. The loss of a single incisor materially interferes with the correct pronunciation of these letters.

Fig. 13



Outline drawing of the oral parts used in the production of speech, and the relation of the tongue to the teeth and the palate. (After Salter.) (*TH*) Position for pronunciation of *TH;* (*DS*) for "d," closure complete, and "*S*," closure incomplete; (*Ch*) as in *Liebchen;* (*Ch*) as in Scotch *och;* (*K*) for "k" and "g" hard.

In *L*, the closure of the parts is in the middle line and the opening at the sides. The sound is obtained by applying the lingual extremity firmly against the gums behind the maxillary incisors in such a way as to leave open lateral spaces, and is generated by the passing of air through these side apertures.

An edentulous person can speak without the presence of teeth; but it is extremely likely that if it were possible for a person to be edentulous from birth and throughout life, the pronunciation of the consonants of the alphabet and of certain words would be almost impossible. The following interesting case exemplifies this point: A patient, aged twenty-two years, who is believed to have congenital absence of the crowns of the teeth, and whose mouth at the present time exhibits a unique appearance, as if all the crowns of the perma-

nent teeth had been levelled with the gum, is unable to pronounce such words as "scissors," "thistle," etc., otherwise than as if they were written "thiththers," "thithle." (See Appendix.) Therefore, one uses the term "Correct Speech."

The teeth are not employed in pronouncing all the vowels. It is the majority of the consonants which are produced by their use. Let the reader imagine the mouth to be an empty box during the pronunciation of the letters of the alphabet. If the *vis a tergo* of the respiratory apparatus, acting or non-acting upon the lid of the box (the lips), closes it partially or completely, it follows that if there is a partial closure of the door (*i. e.*, the lips) the *aspirates* are formed. If there is a complete closure the *explosives* are formed. Consonants are, conveniently, thus divided into *aspirates* and *explosives*.[9]

According to Brücke,[12] who differs in his opinions from Salter, there are four so-called Articulation positions found in the production of speech:

(1) Between the lips. (2) Between the tongue and the hard palate and the front teeth. (3) Between the tongue and the soft palate and the back teeth. (4) Between the vocal chords.

Of these articulation positions, the *aspirates* *F*, *V*, and *W* are formed between the lips; the letters *S*, *Z*, and *L* are produced by the concerted action of the tongue, the hard palate, and the front teeth; while *J* represents the third Articulation position.

Of the *explosives*, the first Articulation position is represented by the letters *B* and *P*, the second by *T* and *D*, while the third—that is, between the tongue and the soft palate and the back teeth—produces the letters *K* and *G*.

TABLE OF CLASSIFICATION OF THE PRINCIPAL CONSONANTS.

Articulation Position.	Explosives.	Aspirates.
1. Labial, partly dental	B. P.	F. V. W.
2. Palatal, lingual and dental	T. D.	S. Z. L. Th. Sch.
3. Buccal, lingual and dental	K. G.	J. Ch.*

The reader is also referred to an important contribution to this subject by Oakley Coles.[5]

* "Th" at the commencement of a word such as "their," "this," is also called a denti-lingual.

Too much stress must not, however, be placed upon the functions of the teeth in the pronunciation of letters. As Gutzmann[10] points out: "Only the sibilants (*S*, *Z*, *Sch*, etc.) are frequently affected by the more serious loss or malpositions of the teeth; but these impediments of speech can generally be removed by constant practice, even without any attempts at the regulation of their position."

Ornamentation.—Other Specific Major Functions of the Teeth are Ornamentation, and in connection with certain Ethnic Ceremonial Rites and Customs.

It is obvious that to the civilized mind a beautiful set of teeth is an ornament to any face. Well-formed and well-kept teeth make a plain face handsome, almost as much as the colour of the hair or the brilliancy of the eyes or the character of the skin.

Curiously, the natives of foreign lands consider that mutilation or staining of the teeth is a mark of ornamentation. The Annamese, for instance, paint their teeth with a mixture of nutgalls and iron filings. In some of the rural districts of Japan, married women and betrothed girls have their teeth similarly disfigured with betelnut juice, probably, in this case, to make their owners unattractive to the opposite sex. The Javanese use small files for deforming the shapes of their teeth.

In the jaws of young males of the Wagogo tribes of German East Africa the two first mandibular incisors are chiselled out, for one or more of the following reasons: As an ornamentation, as a tribal mark—as testifying to his powers of endurance of pain, and part of an initiation ceremony—and as a convenient gap for purposes of feeding in cases of threatened lockjaw after tetanus. A skull showing this mutilation, presented by the author, can be seen in the Museum of the Royal College of Surgeons of England. A similar custom obtains today among the aboriginal Australians.[23]*

* Dr. Duckworth[7] has given a careful "description of an Ashanti skull with defective dentition" which is of great interest. The craniological and dental features of a skull of a young Ashanti exhibits marks of quite an unusual kind. Ethnic dental mutilations are not unknown in West Africa, but it is extremely rare to find the maxillary incisors extracted, and still more rarely all four, as in this specimen. There is no doubt whatever that they were removed by artificial means. Sergi[20] shows that the practice of removing incisor teeth is characteristically East African. Here then there is an example of a great exception. The author last named found in some rock-hewn tombs of Abyssinia, referred to the Fifth Century, A.D., that complete removal of all the maxillary incisors had occurred in seven out of twenty-nine crania belonging to a supposed Hamitic race.

The practice of disfiguring the teeth amongst the Indians of Yucatan and Mexico has been going on since the Sixteenth Century, although not so much today as at that period. They used to saw their teeth into various shapes and drill holes in them for the purpose of beautifying the looks of the women.

FIG. 14

Skull of a native of German East Africa. $\times \frac{5}{7}$. At x the site whence the mandibular first incisors were knocked out. There are no sockets in the very thin alveolar process. *Cf.* Fig. 96.

The filing of teeth in the East Indian Archipelago is analogous, amongst girls, with the European custom of "putting up the hair" at the commencement of the first catamenial period.

Other reasons for artificially interfering with this gift of Nature exist. Dampier describes how the Australian aborigines, whom he met

in his travels at the end of the Seventeenth Century, had a universal custom of removing all their front teeth. Some tribes believed that an excessive and disastrous rainfall could be stopped by knocking out their teeth. It has been suggested that, by this wholesale extraction, the reincarnation of the persons so operated upon would be assured.[9] In Queensland, some tribes hold the belief that a girl whose front teeth have been extracted gets good water to drink when she goes to Heaven, otherwise, if she retains her teeth, she has nothing but muddy water. As the late Andrew Lang remarks: "This looks like a fable, meant to reconcile girls to the loss of their teeth, which must have been knocked out for some other reason, perhaps merely as a visible sign that they had passed through the ceremonies making them marriageable."

Howitt,[11] in a singularly fascinating and scholarly work, writes: "The knocking out of the two lower middle front teeth is not confined to boys only (in South East Australia). When a child is from eight to twelve years of age the teeth are taken out in the following manner: Two pieces of the Kuya-mara tree, each about a foot in length, and chisel-shaped, are placed on either side of the tooth to be extracted and driven tightly. Some wallaby skin is then folded twice or three times and placed on the tooth, and a piece of wood about two feet long, being placed against the wallaby skin, is struck with a heavy stone. Two blows suffice to loosen the tooth, which is then pulled out by the hand. This is repeated with the second tooth. As soon as the tooth is extracted, a piece of damp clay is placed on the gums to stop the bleeding. . . . The teeth are placed inside a bunch of emu feathers smeared with fat and are kept for about twelve months, under the belief that if they were thrown away the eagle hawk would cause longer ones to grow up in their places, which would turn up over the upper lip and thus cause death. The boy's teeth are carefully kept by the boy's father, and long after the mouth is healed, he disposes of them in the company of some old men in the following manner: He makes a low rumbling noise, not using any words, blows two or three times with his mouth, and then jerks the teeth through his hand to a distance. He then buries them about eighteen inches in the ground. The jerking motion is to show that he has already taken all the life

out of them, as, should he fail to do so, the boy would be liable to have an ulcerated mouth and a distorted face. This is another instance of the belief that there is an intimate connexion between the teeth and the person from whom they were extracted, even at a distance, and after a considerable time."

The knocking out of a child's canine is held in Northern Formosa to make him stronger and swifter of foot; and teeth are extracted during seasons of mourning.

In Africa and Australia a man's tribe is often recognized by the cut of his teeth, the front members of the series either having been ground to a point or carved away in an angular pattern.[23, 26] It is the custom among the Rejangs—one of the non-Malay tribes of Sumatra—to mutilate the teeth, which are either filed almost level with the gums or sharpened to a point.

Extraction and mutilation of the teeth are very common amongst the tribes of Central Africa (Report of the Wellcome Research Laboratory, Khartoum, 1911). Livingstone was told that the reason, in the Batoka tribe, was that they wished to look "like oxen and not like zebras." Others hold that the sharpening of the teeth gives the owner a ferocious appearance, that it distinguishes man from monkey, and that it may exhibit their cannibalistic proclivities. The teeth (incisors) may be notched on their mesial surfaces only, or on both their mesial and distal surfaces, being either ground to a point, or remaining blunt and wedged apart. Examples of these horizontal slits, or reduction of angles, or chipped surfaces of half the teeth, may be found amongst the various designs adopted by these peoples, and the lower teeth are more commonly removed than the upper (Figs. 15 to 20).

To other extraordinary ethnic disfigurements it may be added that the habit of blackening the teeth, similar to that which obtains in French Indo-China, is universally found in Melanesia, from the Admiralty Isles to the New Hebrides. Familiarity has produced an admiration for its effects, and has initiated an intense dislike to the possession of white teeth like "those of a dog." The natives are in the habit of mixing together and chewing assiduously areca nut, lime, and betel pepper leaf, the result being the accumulation of a black incrustation on the surfaces of the teeth.

The teeth of certain mammals, such as those of the wolf, the sperm whale, etc., form, when collected and strung together like beads, a

FIG. 15

Mutilation of maxillary incisors. Type I. (The Avungara, or Royal House.)

FIG. 16

Mutilations of maxillary incisors. Type II. (The Avungara, or Royal House.)

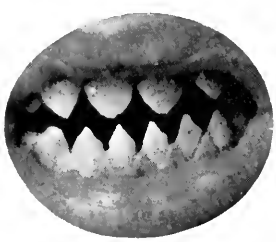
FIG. 17

Mutilations of maxillary incisors. Type III. (The Avungara, or Royal House.)

FIG. 18

Mutilation of incisors. Type IV. (The Zandeh Nyam-nyam tribe.)

FIG. 19



Mutilation of incisors. Type V. (The Zandeh Nyam-nyam tribe.)

FIG. 20

Ethnic mutilations involving the removal of the mandibular first incisors. Type VI. (The Makrakka and Bagaro tribes)

mark of ornamentation in a different sense to that already detailed. Thus, the fishermen of Naples and some of the inhabitants of the

East End of London wear teeth for the dual purposes of ornamentation and "to ward off the evil eye." The natives—both men and women—of Fiji and other islands array themselves with armlets and necklets of rows of teeth—such as those of the sperm whale.

Emotional Expression.—Another Specific Major Function of the Teeth is as a Means for Expressing the Emotions.

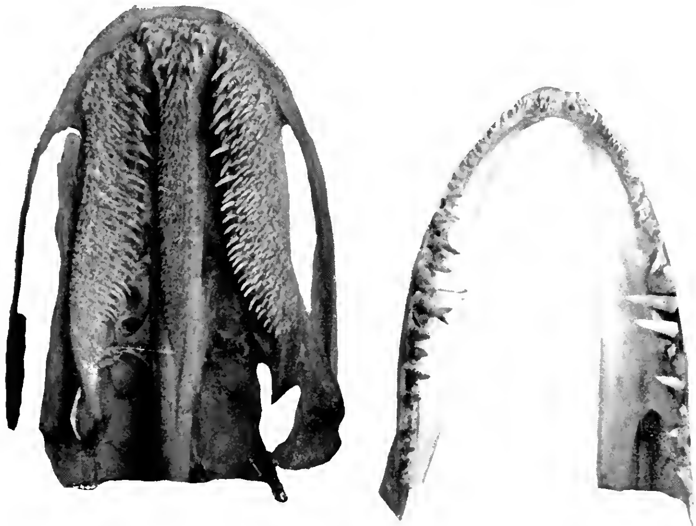
This occurs by the rapid elevation of the lip and the uncovering of the teeth, chiefly the upper canines. The act of sneering and the act of defiance produce certain movements of the muscles of the upper lip, which draw up the angles of the mouth and display the teeth. Annoyance on the part of a person is often accompanied by the undue exhibition of the teeth. The emotion of rage, especially in the insane and in epileptic idiots, emphasizes this fact remarkably well. Not only are the lips raised and they become exposed, but sometimes they are protruded and sometimes retracted, both these attitudes probably being remnants of a habit acquired during prehistoric times, when our simian forefathers fought their enemies with their incisors and canines. The faculties of laughing and broad smiling are accompanied by the laying bare of the upper teeth. Curiously enough, however, as Darwin[6] points out, this does not occur in the chimpanzee. Jealousy and terror in the lower animals are accompanied by a similar exhibition; anger, also, as in the long-tailed monkeys and the baboons. Pleasure, as expressed by a fondled ape, shows itself by the exposure of the teeth, as also does the grinning or the snarling of dogs.

The Minor Functions of the Teeth

Although this division is an arbitrary one, it is convenient to describe the less important natural offices that the teeth collectively are called upon to fulfil, as exemplified in fishes, reptiles, and mammals. They include (I) the prehension of food; (II) for sexual warfare; (III) for the purposes of transport and locomotion; (IV) as weapons of offence; (V) for purposes of toilet; (VI) as chisels; (VII) as mechanical protections to the eyes; (VIII) for sifting food; (IX) as sound-producing organs; (X) for attacking prey.

The Prehension of Food.—Two examples out of many may be mentioned: The pike has a few large recurved teeth anchylosed to the

FIG. 21



A *B*

The teeth of a common pike (*Esox lucius*). × ½. *A*, upper jaw; *B*, mandible.

margin of the lower jaw in addition to numerous smaller ones, distributed elsewhere (Fig. 21). By means of the former the fish is able

FIG. 22

Head of a true dolphin (*Delphinus*). × ⅕.

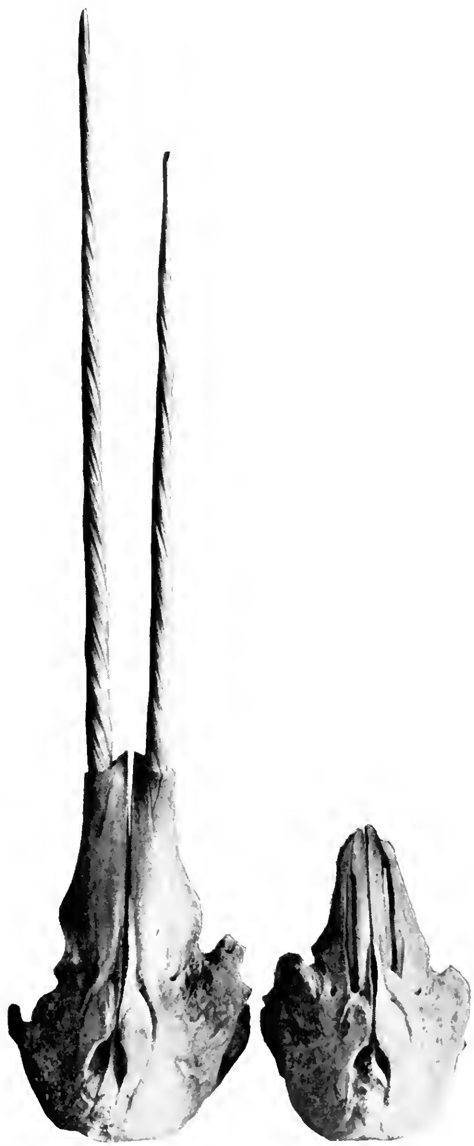
securely to grasp its slippery living prey. The mouth of the dolphin, in the mammalian group, too, presents a good example of organs which

perform this function (Fig. 22)—a function which obtains very largely throughout the natural world.

For Combative Purposes.—Many illustrations might be given; it is sufficient to say here that in the *Mammalia* these functions exist exclusively. Thus the adult male narwhal, an aberrant species of dolphin called also the sea unicorn, has one tusk—a maxillary incisor. Generally, the left one is present, and has a spiral twist throughout its course. It may be twelve feet long, and its curves wind from right to left. The rudiments of the right incisor are seldom developed, probably because this side of the skull is smaller than the left, a fact clearly seen in a specimen in the Museum of the Royal Dental Hospital of London. The animal is a native of the Arctic regions, and feeds on small fish, cephalopods, and crustaceans (Fig. 23).

Another example of teeth used for sexual warfare is found in the canines of the male musk deer (Fig. 24). This small creature possesses no antlers, but what he lacks for the purpose of defence and offence on his head he possesses in his mouth. The musk-deer lives in the mountains of Central Asia, in Thibet, China, and Siberia.

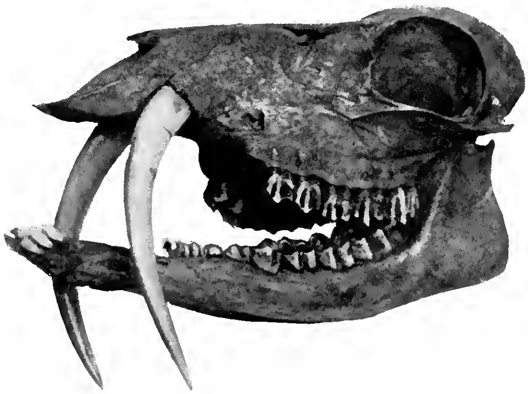
FIG. 23



Skulls of a male and female narwhal (*Monodon monoceros*), viewed from above. × $\frac{1}{24}$. Usually the male has but one (the left) tusk, the right being undeveloped.

A further instance may be given in the mandibular incisors of the Indian rhinoceros, who fights, not with his horns, as is generally believed, but with his teeth. The English horse occasionally uses his incisors for the same purpose.

FIG. 24



Skull of a male musk deer (*Moschus moschiferus*). × ½.

For the Purposes of Transport and Locomotion.—In India it is not an uncommon thing to see the elephant transporting from place to place bales of goods or piles of timber by means of his tusks. The beaver, with the help of his chisel-like incisors, carries the scaffolding for his home on the banks of the river for considerable distances (Fig. 25). The domestic cat carries her kittens from place to place by means of her teeth; and the Indian of Mexico makes many uses of his teeth and jaws as a third hand for holding the reins of his horse, supporting his clothing and fire-arms while fording rivers, and graduating the weight of loads.

The walrus is said to use its canine teeth for dragging itself out of the water on to the ice floes in the North Pacific Ocean and the polar regions of the Atlantic Ocean. It is enabled, by means of its powerful tusks, also, to dig out of the mud certain molluscs on which it principally feeds.[19] It also eats starfishes, sandworms, and shrimps.[17]

Allied to this function is that of anchorage, as exemplified in the extinct *Dinotherium*, a mammal which, although living in Pleistocene times, may today be classified among the Perissodactyle ungulates,

midway between the tapir and the elephant. (See Chapter XVI.) This mammal had aquatic habits, like the hippopotamus. The tusks correspond to or are homologous with incisors. The symphysis of the mandible is prolonged and deflected downwards, carrying two incisors, which are two feet in length, being larger in the male than in the female. By means of these the animal was enabled to anchor itself to whatever it wished.

FIG. 25

Skull of a beaver (*Castor fiber*). × ⅓. The chisel-shaped incisors are deeply pigmented.

As Weapons of Offence.—The teeth, amongst certain groups of animals, are largely used for killing their prey or killing their enemies. This is well exemplified in the viperine snakes, where the teeth are so modified as to become poisonous fangs, in contra-distinction to the pythons, who kill their prey by crushing it in the coils of their bodies.

A remarkable instance of the teeth being used for the purpose of destroying its foes is presented by the Siberian mammoth, which roamed over the Northern Hemisphere thousands—perhaps four hundred thousand years ago. The body of one of these huge extinct animals was discovered in 1901, and is to be found in the Museum of the Academy of Sciences at St. Petersburg.[15] It is a unique specimen,

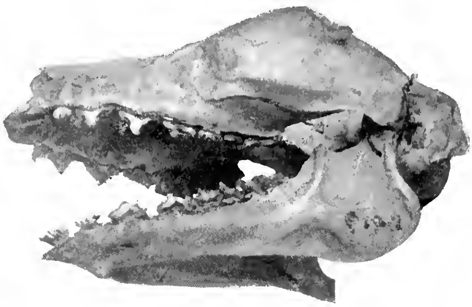
inasmuch as not only fossil remains were found, but, on account of its being frozen in the glacial mud of the Siberian Sea, the hair and the wool and other soft parts have been retained. The stomach contained some undigested food, and grass was found between the molars. It is believed that this particular Russian specimen met its death by sinking into a grave of sand and clay, from which it was unable to emerge, which, on becoming flooded and frozen, retained its buried occupant for hundreds of centuries.

The Texan mammoth — that is, *Elephas imperator* — measured fourteen feet six inches in length, the animal standing fifteen feet high. Similarly to the Siberian mammoth it used its incurved tusks (incisors) for killing its enemy by hurling it into the air. Most of the non-human prey of this ancestor of the modern elephant possessed in those preglacial times, protective armour over their bodies. It was impossible, therefore, for their larger enemies to kill them in any other way than by throwing them into the air and smashing their protective armour on the rocks.

For the Purposes of a Comb.—An interesting little creature—the Flying Lemur of India and the Malay Peninsula, called the *Galeopithecus volans*—is said to use its mandibular incisors as a comb for cleaning its fur. These incisors are pectinate in form, and constitute an admirable instrument for toilet purposes. The *Galeopithecus* belongs to the insectivorous animals, although it eats leaves and fruits, and is not one of the *Primates*, with which it used to be classified. It attains to the size of a cat, and has a lateral expansion of the skin of the body, supported by the limbs and tail, which when extended forms a patagium, by which means it floats through the air in a downward direction. The pectinate incisors of the flying lemur are analogous with the epithelial papillæ on the upper surface of the tongue of the cat, that is to say, both these different organs—the incisors and the papillæ—are used for performing the same function, namely, cleaning the fur (Fig. 26). The pectiniform mandibular teeth of the hyrax are not so complex in character as those of the former. Their use is unknown. Allied to this function, attention may be drawn to the outermost of the eight lower anterior teeth of the giraffe. This tooth, which is bilobed, is used by its possessor as a comb for removing leaves

of trees without doing harm to the young twigs. A deer, in browsing, eats all leaves and young twigs of branches, but the giraffe carefully avoids damaging the trees themselves.

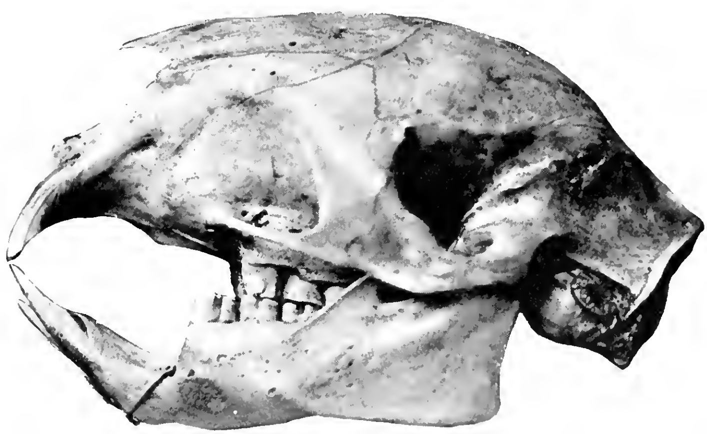
FIG. 26



Skull of a flying lemur (*Galeopithecus volans*), showing its pectinate mandibular incisors. × $\frac{9}{10}$.

Chiselling.—Rodent animals, like the squirrel, porcupine (Fig. 27), and rat, possess chisel-shaped teeth, with which the former fracture

FIG. 27



Skull of a porcupine (*Hystrix cristata*). × $\frac{1}{1}$. The molars in this genus, as in those of the old world generally, are only partially rooted.

the hard shells of nuts. The *Balistes*, or file-fish of tropical seas, has incisiform teeth for boring holes in the hard shells of molluscs in order to extract the soft parts. The pearl oysters in the fisheries of Ceylon

are thus attacked. It is interesting to note, parenthetically, that the oyster has other enemies besides Man and these carnivorous fishes. The common starfish of our British coasts prey upon the oyster; and although it takes a weight of seven pounds to produce mechanical artificial opening of the shells of this bivalve, the starfish can, by constant pulling on each shell, gradually exhaust the power of the muscle of the foot of the oyster and force the shells apart. It is said, too, that the octopus, which is unable to exercise such pressure on the shell of the oyster, because of its great disparity in size, waits until the mollusc opens its shell voluntarily, and that, at that moment, it places a pebble in the space thus produced, an action which, of course, prevents the closing of the shells.

FIG. 28

Skull of a male babirussa of the island of Celebes (*Babirussa alfurus*). $\times \frac{1}{4}$. The maxillary canines are placed extra-orally.

As Protections to the Eyes.—The curvatures of the upper and lower canine teeth of the wild pig and boar (Fig. 28) found in the Malay Archipelago are so constituted as to form a protection to the eyes when the animal is seeking food in the bush. The presence of these huge tusks prevents any injury occurring by any of the fallen boughs or trunks of trees.* So curved do these lower canines become that,

* This statement is doubted by Wallace ("Malay Archipelago," vol. i), who believes that they are monstrous overgrowths occurring in the male sex only, as females who similarly hunt for their food do not possess them.

persistently growing, in some instances they may ultimately form a circle; so much so, that the natives of New Guinea break off the upper tusks of the wild boar to allow the lower ones room for this growth into circular form. When the development is complete the animal is slain and the teeth are used as armlets for jewelry and other decorative purposes.

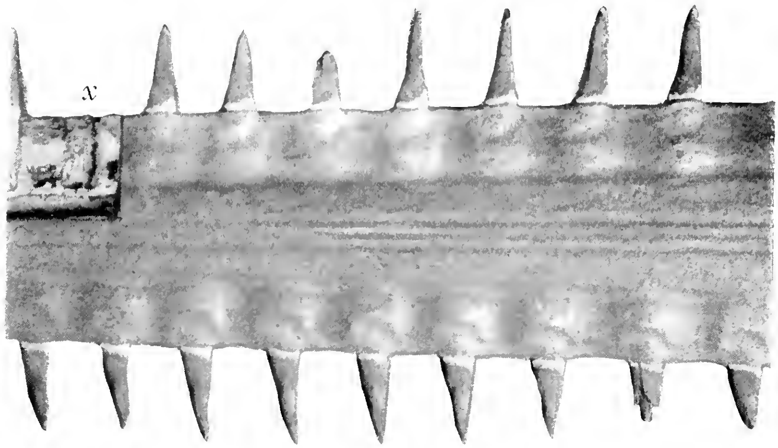
As Sieves.—Amongst the chætodonts—a genus of coral fishes of the tropical seas living in the neighbourhood of coral reefs—which are both carnivorous and insectivorous in type, the teeth are found to act as a sieve. They are very long, numerous, and slender, very thickly placed, and afford an example of the *dents en velours* in the mouth of fishes. The chætodont is able to sift, from a mouthful of water, the essential parts of its food, like the whalebone whale, but by different means. It may be mentioned that a small coral fish, *Toxotes jaculator* by name, is able to project from the surface of the river in which it lives a stream of water on to flies which are hovering over it, thus drowning them. It is said that the natives of the Malay Archipelago keep this fish in aquaria in captivity for the purpose of watching it perform this trick.

As Sound-producing Organs.—Some naturalists have given the name of the "drum" to *Pogonias*—a fish found on the coasts of the United States.[4] They believe it is enabled to produce the sound, by the rapid clapping together of large molariform teeth found on the pharyngeal bones. Travellers on anchored steamers imagine they can detect these sounds in the stillness of the night. Little is known as to the actual cause; by some it is thought to be due to the fish beating their tails on the keels of the ships, so as to get rid of certain parasites attached to their bodies. Other observers also state that the sunfish and the *Balistes* are able to produce sounds in their mouths.

For Attacking Prey.—Lastly, the rostral teeth of sawfish (*Pristis*) (Fig. 29)—structures entirely different and far removed from the oral organs—are used for the purpose of tearing open the abdomens of large whales and soft-bodied fish of the greater seas and oceans. The rostrum provided with the teeth acts as a veritable saw, while

the oral teeth are concerned in the mastication of the intestines of the prey, thus being used in the same way as the teeth of many other fishes.

Fig. 29



Rostrum of sawfish (*Pristis*). × ½. At *x* a socket of a tooth has been exposed.

FUNCTIONLESS TEETH

Some teeth are probably functionless with regard to mastication or comminution of food, namely, those on the branchial arches of whales—as in the *Selache maxima* of the Northern hemispheres and the British coasts—and also on the osseous gill arches of the sun-fishes.

SUBSTITUTES FOR TEETH

Other organs may act in the same way as teeth; for instance, the spinal processes of the under surface of the vertebræ in *Dasypeltis scabra*, an egg-eating colubrine snake of South Africa. This is a small snake, which crams relatively large hens' eggs—which are crushed as they traverse the œsophagus—into its mouth, and may become so inflated as to resemble a small football with a tail attached to it.[24] Probably the reason it takes the unbroken egg into its mouth is to prevent waste of food.

The hard sheaths which form the cases for the jaws of the turtle or tortoise, homologous with the beaks of birds, and the jaw-bones themselves, as in the *Sphenodon*, also subserve the masticating functions of the teeth. The latter, also known as the *Tuatera*, and commonly, but incorrectly, regarded as a lizard, found inhabiting two small islands off the coasts of New Zealand, displays a unique type of dentition, inasmuch as young individuals possess in the front of each jaw a pair of chisel-shaped teeth, followed behind by a double row of closely placed small teeth, separated by a groove, into which a single mandibular series passes when in use. In old creatures the lower teeth become worn away, and the edge of the jaw itself highly polished and employed for dental purposes.[1]

THE APPLICATION OF DENTAL FUNCTIONS TO THE PURPOSES OF ART

Nature and Art are often closely allied in the matter of the shapes, structure, and uses of the teeth. Civilized and barbaric man, observing these functions, have utilized the principles of their construction and methods of employment in inventing and producing domestic and other articles for every-day service. Inasmuch as it is most probable that the recognition of the character of the sutures of the human skull gave origin to the invention of dovetailing, adopted in the manufacture of wooden boxes, so teeth have also furnished examples for copy by mankind.

Probably the most striking and the closest of all these adaptations is that of the poison fang of the viperine snakes. Here is essentially a surgical instrument for the infliction of a punctured wound—and the injection into that wound of a deadly fluid—which is provided with a canal which terminates near but not at its extremity. The surgeon has used the principle of the structure of the poison fang for the invention of the hollow needle of the modern hypodermic syringe. (See Fig. 65.)

Further, the millstone probably owes its origin to the shape and functions of the molar of the elephant; the teeth and jaws of the skate (*Myliobatis*) gave rise to the invention of the crushing mill and roller;

the jaws of the wolf-fish to the nut-cracker; the incisors of the hippopotamus to the steel adze of Europe and the stone adze of Polynesia; the incisors of the beaver to the chisel; the tusks of the walrus to the scaling fork (*Sturmgabel*) in use in Sixteenth Century warfare, and at the present day as an ice anchor or grappling hook in the Arctic or Antarctic regions; the jaws of the shark to the deer trap of India; the jaws of the dolphin to the rat trap; the jaws of the snake to the "throwing stick" of New Caledonia; and the rostrum of the sawfish to the spears and wooden swords armed with sharks' teeth employed, even today, by the natives of Australia and the inhabitants of Mexico.[27]

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CHAPTER III

GENERAL NUMERATION AND TOPOGRAPHY

The Numbers of the Teeth in Fishes, Reptiles, and Mammals.—Their General Osseous Relationships.—Dental Notations.—The Typical Mammalian Formula.—The Numerical Reduction in Man.—Theories Regarding the Incisors.—The Factors in the Production of the Diminution in Number.—Instances of Redundancy and Deficiency.

NUMBER OF TEETH

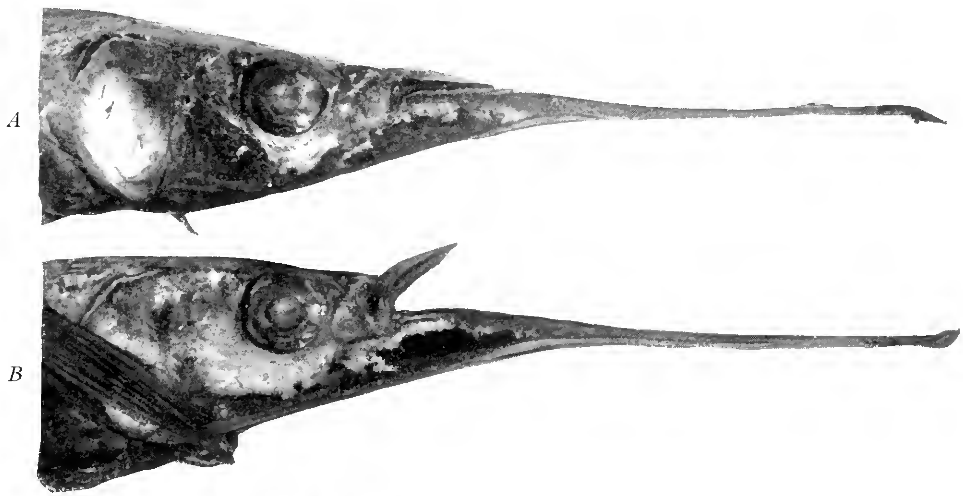
Following up the train of thought already indicated in Chapter I, and arguing again "from the known to the unknown," it would seem that the number of teeth in the lower animals and in Man should now engage the attention of the reader. The number of teeth in the human mouth is generally more or less obvious to all. In dealing with the question, the study begins with the toothed vertebrates, and considers the fishes first, then the reptiles, and finally the mammals. This is the order of Creation, and is followed in these pages throughout. The dentitions of fishes will be only slightly glanced at, and those of reptiles also, the main point being the characteristics of the teeth of Man.

It is important to note that teeth are not classified into incisors, canines, etc., as Anatomists usually speak of them, in the fishes and reptiles. The reason of this will be apparent at once when the definitions and significance of these terms are realized. Roughly to differentiate the teeth in the mouth of a fish or reptile one describes them as "front teeth," or "back teeth," or "pharyngeal teeth," or "lingual teeth," according to their situation.

Fishes.—Generally speaking the jaws are elongated and narrow to accommodate a vast number of teeth. In *Hemiramphus* (Fig. 30) the mandible—itself toothless—is of great length to enable this fish to shovel up into its mouth crowds of aquatic worms and insect larvæ, on which it subsists, from the sandy shores of the rivers which it inhabits.

In this class the number of teeth varies very considerably. Instances are found where they are entirely absent, as in the pipe-fish and the *Hippocampus* (Fig. 31). These fishes probably live on small annelids (worms) and require no dental armament for the purpose of comminuting their food. In the myxine and the *Bdellostoma* one single tooth is found, situated on the median line of the palate. It has been pointed out in Chapter II that the exposed surface of this tooth is corneous, having beneath it a small cap of enamel and dentine. There are other teeth in the mouths of the pike and the *Bdellostoma*,

FIG. 30



Head of *Hemiramphus*. × 1/1. *A*, mouth closed; *B*, mouth open.

situated on the lingual bones which partake of the nature of *dents en cardes*. In the *Ceradotus* there are two small chisel-shaped maxillary and two mandibular ridged plates, the two lower being larger than the upper. These probably partake more of the nature of bone than of the character of teeth. The *Ceratodus* (Fig. 32) is interesting as being probably the connecting link between the fishes and the amphibians (frogs and toads). It is the so-called lung fish of Australia, may attain the length of six feet, lives amongst mud and dead leaves, and rises at intervals to the surface to breathe. The settlers of Queensland have named it the Burnet River salmon.

These are instances of fishes which possess few teeth or none at all; but between these two groups and the fishes which present great numbers of teeth, there are countless variations. The pike (*Esox lucius*) possesses enormous numbers of teeth, which are practically incomputable. In its mouth examples of *dents en brosses*, *dents en cardes*, and also *dents en velours* are found.

Fig. 31

The sea-horse (*Hippocampus*), belonging to the Family *Syngnathidæ*, of Sub-order II (*Dophobranchii*), of Sub-class III (*Teleostomi*), of Class V (*Pisces*). × 1/1.

Fig. 32

A

B

Jaws of the Australian lung-fish (*Ceratodus*), of Sub-class I (*Dipnoi*), of Class V (*Pisces*). × 1/1. *A*, upper jaw; *B*, lower jaw, showing the dental plates.

Reptiles.—Amongst the reptiles, the number of teeth is never so great as in the fishes, nor so small as in some mammals and the fishes above named. Generally speaking, the number is not fixed so as to be characteristic of any class; thus *Varanus* (Fig. 33), the monitor lizard, has about sixteen upper and fourteen lower teeth. The batrachian, *Triton cristatus* (a newt) has many teeth on the superior, inferior, pre-maxillary, and vomer bones, the latter being extremely small.

Mammals.—With regard to the mammals: the whales, that is to say, the toothed whales, the *Odontoceti*, afford the fewest number

of teeth. For instance, the beaked whales ("Bottle-nose" whales of the English coasts) have one pair of teeth in the mandible, which are invisible during the fresh condition. There is a Bottle-nose whale named the *Hyperoödon rostratus*, which is frequently stranded on the British coasts. Its length is usually about thirty feet, and it yields oil and spermaceti. In this mammal the pair of teeth is situated in the front of the mandible; whereas, in the *Mesoplodon* (a "beaked" whale, fifteen feet in length) they are situated, as the name implies, in the middle of the jaw. In the Natural History branch of the British Museum, Kensington, there is a specimen of *Mesoplodon layardi*, which shows these two teeth enormously grown, curving over the upper jaw, so as almost to prevent the mouth from being

FIG. 33

Skull of a monitor lizard (*Varanus*). $\times \frac{4}{5}$.

fully opened. They are strap-like in shape. The narwhal, as has already been described, has two tusks. Arnux's whale (the *Berardius arnuxi*), of the New Zealand waters, possesses two pairs of lower teeth, while the *Grampus griseus* has two teeth at each side of the mandible. They become, in old individuals, reduced in number to one on each side of the lower jaw.

Amongst the Marsupials there are two mammals which possess a small number of teeth: for instance, the *Tarsipes*, a small rat-like animal, which is insectivorous and nectar-eating, with a long prehensile tongue, has the lower incisors procumbent, and a few small teeth opposed to them in the maxilla. The Australian water-rat (*Hydromys*) possesses only twelve teeth.

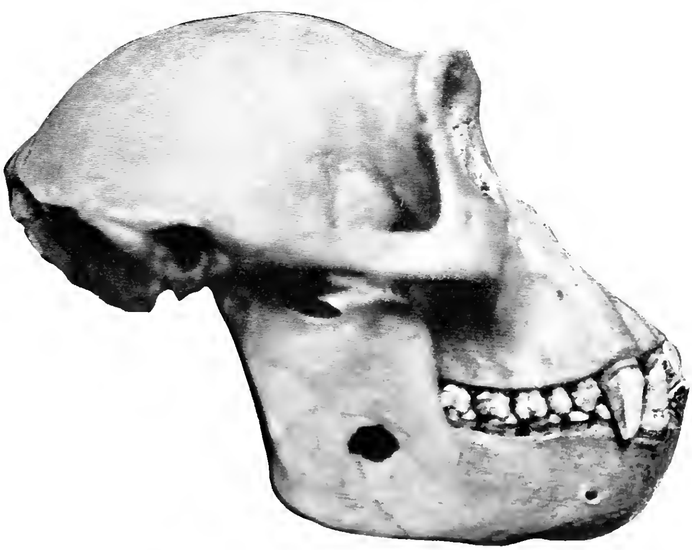
Generally speaking, rodents have twenty teeth. The two-toed

sloth (Fig. 318) has eighteen, and it is monophyodont. Man, and the apes of the Old World, *i. e.*, Africa, etc., such as the gorilla, have thirty-two teeth (Fig. 34). The New World (American) monkeys

FIG. 34

The teeth of an adult man. $\times \frac{1}{2}$.

FIG. 35



Skull of a chimpanzee (*Anthropopithecus troglodytes*). $\times \frac{1}{3}$. The third maxillary molars are smaller than either of the others.

possess thirty-six (Fig. 36). An excessive number of teeth is found in the common porpoise, where ninety dental organs exist. The Gangetic dolphin, which lives in the fresh water of the Ganges, Brahmaputra, and Indus Rivers, possesses one hundred and twenty teeth. It is difficult, at first sight, to account for this huge number of teeth in a mammal, particularly one adapted to aquatic habits; but when it is recalled that this dolphin is quite blind and has to grope about at the bottom of the rivers for small fish, it will be found that Nature

FIG. 36

Skull of a New World monkey (*Cebus*). × $\frac{4}{5}$. There are three pairs of premolars in each jaw.

has beautifully adjusted means to an end by providing it with a large number of teeth. The true dolphin may have more, the number varying from one hundred to one hundred and ninety. Again, there is a beneficent example of Nature in providing this creature with ample means for obtaining its food. The greatest number of all, however, is reached by a fresh-water dolphin which inhabits the Rio de la Plata. Of all mammals it has the greatest number of teeth, namely, about two hundred and fifty.

OSSEOUS RELATIONSHIPS

In Fishes.—Teeth may vary in position or situation. The *Teleostei*, or bony fishes, present an important dental armament. It is necessary

to note the names and positions of the bones which form the walls, floor, and roof of the mouth of these fishes, for it will be seen later, with regard to the bones of the skull of the snake, and with regard to the development of the human jaws, that a knowledge of the bones forming the reptilian and the piscine skull is essential.

The upper margin of the mouth is bounded by the right and left Pre-maxillaries above, which are frequently tooth-bearing bones; above, and parallel, are the right and left Maxillaries. The lower margin is bounded by the Pre-mandibulars or Dentary bones. The

Fig. 37

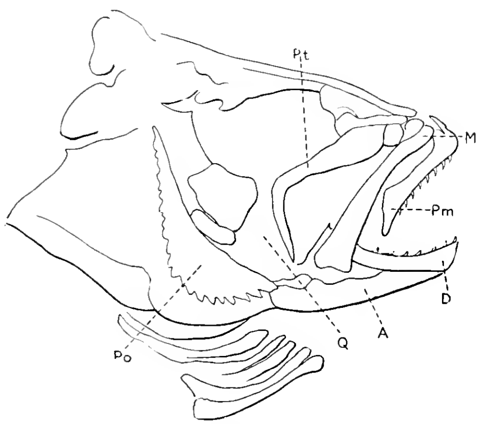


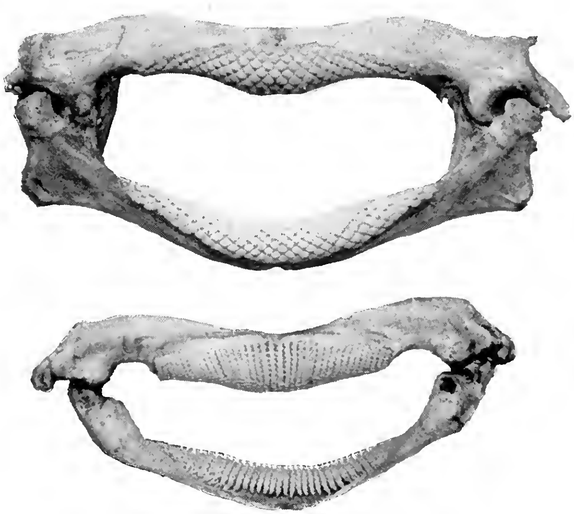
Diagram of the bones of the head of a teleosteous fish. (After Günther.) *Pm*, the premaxilla; *M*, the maxilla; *D*, the dentary; *A*, the articular and the angular; *Q*, the quadrate; *Pt*, the pterygoid and palate; *Po*, the præoperculum.

roof is formed by the Vomer in the middle, articulating with the Basi-sphenoid, and bounded laterally by the Palatine, the Pterygoid and Ento-pterygoid. The floor is formed by the Lingual bones, which form a median longitudinal plate, to the sides of which are attached the lower bones of the pharyngeal arches. Articulating with the Maxillary bones are the Pre-orbital above, and the Angular and Articular below. The Angular articulates with the Quadrate, and the Pre-orbital with the Pre-frontal and Turbinal. The mandible of a fish, such as the perch, consists of the Dentary, Articular, and Angular bones (Fig. 37). In addition to this, the pharynx is

strengthened by the presence of one to six or more Pharyngeal bones above and below.[4]

The situations of the Dental Systems in fishes is interesting. Thus, in the perch, the Pre-maxillaries and the Dentary are the only bones which carry teeth. In the roach and the barbel, the Pharyngeal bones alone have teeth placed upon them. In the *Labrus* and *Scarus*, they are found on the Pre-maxillary, Pre-mandibular, and Pharyngeal bones. Amongst the sharks and rays (Fig. 38), which have cartilaginous skeletons, they are placed upon the maxillary cartilage. It

FIG 38



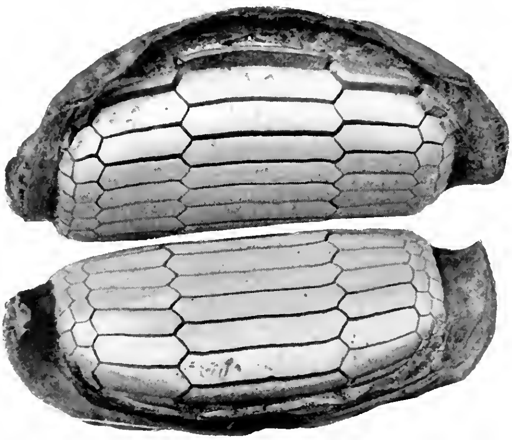
Jaws of one of the rays, showing sexual differences in the shapes of the teeth. The jaws are widely distended. × $\frac{4}{5}$.

has already been pointed out that in the mouth of the pike great numbers of teeth exist; and it will suffice now to say that they are situated on the Vomer, the Palatine, the Lingual, the Pre-maxillary, and the Dentary bones.

As examples of irregular positions of the situation of teeth, it may be mentioned that the *Pristis*, or sawfish, has them on the rostrum; the lamprey on the lips, the myxine on the centre of the palate, and the *Myliobatis* (Fig. 39) across the symphysis of the lower jaw.

In Reptiles.—The situation of the teeth in the reptiles and batrachians is much simpler. There may be, generally speaking, four: (1) On the jaws only, as in the crocodile, and many lizards—for instance, Varanus—while in the snakes—the adder, for instance—they are absent from the Pre-maxillary bones, and from the lower jaws of frogs, but they are present on both the upper and lower jaws of the newt; (2) on the jaws and Pterygoid bones, as in the iguana and the chameleon; (3) on the Palatine and Pterygoid bones, as in the serpents and the viperine snakes; and (4) on the Vomer, as in the *Batrachia* generally.

FIG. 39



Jaws of the eagle ray (*Myliobatis*), showing the flat, polished, hexagonal teeth, and the cartilages in which they are imbedded. Development proceeds from within outwards. $\times \frac{4}{5}$.

In Mammals.—It is obvious that in the *Mammalia* teeth are found, as a rule, attached to the margins of the jaws. A few exceptions exist, however; for instance, *Echidna*, the spiny ant-eater—a monotreme of Australia, New Guinea, and Tasmania—is edentulous (Fig. 326). This curious creature possesses a muzzle, which is an elongated slender beak, enclosing a long extensile vermiform tongue. On the Pterygoid bones, as well as on the tongue, there are spines of an epithelial character. The *Echidna* is nocturnal in its habits, lives in rocky and sandy districts, and rapidly burrows into the earth on the approach of danger. Its food is ants.

Again, the South American ant-eaters have no teeth; the tongue is

covered with viscid saliva from the maxillary glands, which causes the ants from an ant-hill to adhere to it. The Great Ant-eater, terrestrial in its habits, and living in the swampy forests of South America, is also edentulous, and the arboreal *Tamandua*, or Lesser Ant-eater, similarly devoid of teeth. Again, the Scaly Ant-eater (*Manis*), which resembles, at first sight, a reptile, is edentulous. This animal is found in South Eastern Asia and Ethiopia—Africa south of the Desert of Sahara.[12] Amongst the mammals, also, it must be noted that in the *Mystacoceti* or baleen whales—whalebone whales—there are rudimentary teeth which are very early shed. Whalebone is interesting because its matrix morphologically corresponds with enamel, being produced by a cornification of the epithelial coverings by vast numbers of vascular papillæ, which are long thread-like processes, arising from persistent pulps and penetrating the hard substance of the whalebone plates. In the whalebone whales, which are quite distinct from the toothed whales already noticed, these plates hang down from the roof of the mouth transversely to its long axis, and extend nearly along its whole width. In the middle line, similar plates are found. The plates act like a sieve, forming a series of parallel, narrow, elongated, triangular laminæ, their inner edges being frayed out into a fringe. The longest plates in the Greenland whale measure twelve feet, and number three hundred and eighty. In the Rorquals the length is a few inches. Baleen whales do not require teeth for the purpose of alimentation, for they eat pteropods, molluscs, and very small fishes, on account of the narrowness of the œsophagus for the passage of larger fish.[11]

Sir Harry Johnstone[9] writes: "The 'right' whales open their mouths when they find themselves in the middle of shoals of minute crustaceans and pteropods, and then close the mouth, forcing out the water through the sieve of the whalebone. The tiny organisms that are prevented from escaping by the fringe of the baleen plates then fall on to the broad tongue which lies in the great hollow of the under jaw, and in this manner are swallowed through the very narrow gullet. In the 'right' whales the throat is so narrow at the swallow that it would probably allow nothing to pass of larger size than a mouse. When the mouth is shut, the long fringes of whalebone fold backward, the front

plates lying below the hinder ones, so that in a sense the long ends of the whalebone are partially contained within the approach to the gullet. When the animal opens its mouth widely, the whalebone springs forward till it is perpendicular."

The whalebone whales include five classes: (1) The *Balæna* (right whales), of Greenland and Spitzbergen, in which the baleen is long and black; (2) the *Neo-balæna*, of New Zealand and Australia, in which the baleen is long and white; (3) the grey whale of the North Pacific, a rare mammal, in which the baleen is short and yellow; (4) the *Megaptera*, or hump-backed, so-called because it lies sometimes on its side in the water, the body being submerged, and extends upwards a flipper which is bright white in colour, and may rise to a height of ten feet above the surface of the water; and (5) the *Balenoptera*, or rorqual, "finned whales," "finned backs," and "razor backs." Amongst this genus is the most gigantic of all animals, the *Balænoptera sibbaldi*, which reaches a length of eighty feet, and is found in the seas between Scotland and Norway.

Sufficient has been said here to show the great characteristics of the two classes of whales. Both at first have rudimentary teeth. In the *Odontoceti* these grow and persist, while in the baleen whales they are shed, and the mammal remains edentulous. (See Chapter XVI.)

DENTAL NOTATIONS

The number of the teeth in any given Mammalian dentition is expressed by what is known as a dental formula. There are several ways of graphically depicting such a formula. Taking collectively the type of dentition found in Man, and dealing with one side of the skull only, this may be simply written as follows:

Incisors $\frac{2}{2}$ Canine $\frac{1}{1}$ Premolars $\frac{2}{2}$ Molars $\frac{3}{3} \times 2 = 32$. That is, there are altogether in each jaw, four incisors, two canines, four premolars, and six molars. It is also convenient to express the members of the deciduous or "milk" series in small type, as i. c. pm. and m. To indicate whether a tooth belongs individually to the maxillary or mandibular bones, one writes, for example, Pm^2 for the second left

maxillary premolar, $^{2}\mathrm{Pm}$ for the second right maxillary premolar, Pm_2 for the second left mandibular premolar, and $_{2}\mathrm{Pm}$ for the second right mandibular premolar. Similarly, the maxillary and mandibular teeth of either side may be represented by placing a numeral above or below the other indicating them, thus:

$$\mathrm{I}^1, \mathrm{I}^2, \mathrm{C}, \mathrm{P}^1, \mathrm{P}^2, \mathrm{M}^1, \mathrm{M}^2, \mathrm{M}^3 \quad \text{and} \quad \mathrm{I}_1, \mathrm{I}_2, \mathrm{C}, \mathrm{P}_1, \mathrm{P}_2, \mathrm{M}_1, \mathrm{M}_2, \mathrm{M}_3.$$

Clinically it is, in addition, of service to use the following Symbols for the permanent teeth.

$$\begin{array}{c|c} 8\;7\;6\;5\;4\;3\;2\;1 & 1\;2\;3\;4\;5\;6\;7\;8 \\ \hline 8\;7\;6\;5\;4\;3\;2\;1 & 1\;2\;3\;4\;5\;6\;7\;8 \end{array}$$

and for the deciduous series:

$$\begin{array}{c|c} e\;d\;c\;b\;a & a\;b\;c\;d\;e \\ \hline e\;d\;c\;b\;a & a\;b\;c\;d\;c \end{array}$$

The typical number of Eutherian teeth is forty-four. An extinct mammal, named the *Homalodontotherium*, possessed the typical number, namely, forty-four.[15] They represented transitional stages in regard to shape, that is to say, the third incisor was rather like a canine, the first premolar was rather caniniform also, the fourth premolar being molariform; so a gradual transition from incisors to canines, then to premolars and molars, was observed in the jaws of this mammal.[14]

The *Otocyon megalotis*, a curious aberrant member of the dog family, of South and East Africa, a kind of fox with long ears—as the name implies—has an additional molar above and below on either side, making forty-eight teeth entirely.[14] This is an example of the greatest number of teeth in a heterodont placental animal.[6]

NUMERICAL REDUCTION IN THE HUMAN DENTITION

Man has, in normal conditions, thirty-two teeth; there is, therefore, a considerable reduction from the typical mammalian formula.[10] Which teeth are absent? The third incisor and the first and second

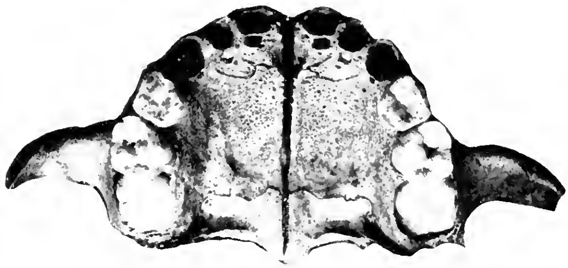
premolars are said to be. It is probable that the first and second premolars are suppressed from the series, as it is the rule—except in the polyprotodont marsupials—that when premolars are missing, the first two of the series disappear. There is, however, some doubt as to whether it is the third incisor which has disappeared in the course of evolution from the mouth of the immediate ancestors of Man.*[17] Those naturalists who favour the transitional theory, such as Hensel, and who take the *Homalodontotherium* as a type, consider that it is the third incisor which has gone, for there is no resemblance whatever, from the point of view of shape or size, between the second incisor and the canine. Baume[3] and H. H. Edwards[6] hold that the first incisor is the absent tooth.

Albrecht[1] (and he is supported by Sir Wm. Turner[15] and A. Wilson[16]), however, considers that it is the second incisor which is missing. He believes that the premaxillary bones are developed from two centres of ossification, that there are, therefore, four premaxillary bones altogether. The boundaries of the premaxillary bones are said to be as follow: In front, the median suture of the superior maxillæ; behind, a suture passing between the second incisor and the canine in front, and ending in the anterior palatine canal. But this German observer believes that there are two sutures, one on the distal surface of the first incisor, the other on the mesial surface of the canine, which separates the ectognathic and mesognathic parts, and as already pointed out, thinks that there are two centres of ossification for each premaxillary bone (Fig. 40). He further considers that the osseous division in cleft palates runs along the first-named suture, that is, the one between the first and second Incisor. Therefore, the argument is that the second Incisor, as we speak of it, is really a pre-canine or the third Incisor. Cases have been rarely recorded of tripartite palates, which carried four incisors on the premaxillary bone, and another incisiform tooth (pre-canine) existed also beyond the cleft. If the definition of the maxillary incisors, as given later, be accepted as teeth implanted

* It is important to note the fact that neither has prehistoric man, nor have any of the anthropoid apes, lemurs, or bats, ever possessed six incisors in each jaw. The "disappearance" of a third incisor, or the "suppression" of the two anterior premolars, does not here imply the existence of these teeth, as they have never been evolved.

in the premaxillary bone, the conclusion that the "pre-canine" is the same as the third incisor of the normal mammalian dentition is arrived at, and, therefore, that the lost incisor in man is probably the second incisor.

Fig. 40



Palate of a child, aged about five and a half years, in which the maxillary and premaxillary sutures remained patent. $\times \frac{9}{10}$. Each premaxillary bone consists of two portions, and carries an incisor.

Variations in Number of Teeth.—Instances of the numerical deficiency and redundancy of teeth are frequently encountered in practice. They occur more commonly in the upper than the lower jaw.

Fig. 41

Model of mouth of a boy having six permanent incisors. The canines are just erupting. $\times \frac{9}{10}$. Original in the possession of Mr. Sidney Spokes.

Fig. 42

Photograph of the mouth of a man, showing seven maxillary incisiform teeth.

Incisors.—Fig. 41 is a photograph of a plaster cast of the mouth of a boy showing six well-formed maxillary incisors, the original in the possession of Mr. Sidney Spokes; and Fig. 42 that of a man, aged

twenty-eight years, who had, in the superior inter-canine region, implanted in the premaxillary bones, seven teeth—all fully erupted and the majority well formed. The plaster casts and photographs show the actual condition. From an examination of the jaw it was evident that the inter-canine region was exceedingly broad; it measured no less than 34 mm., while the mandibular inter-canine region measured 18 mm. The normal adult measurements are about 28 mm. in the upper and 18 mm. in the lower jaw. It is obvious that both the ectognathion and the mesognathion are broader on the right than on the left side, accommodating four teeth to the other three. It is very difficult to interpret the condition and correctly name the teeth. Morphologically they would appear to be the right first and second incisors, a third incisor (the pre-canine of Sir William Turner) and a supernumerary first incisor, all in the right premaxilla; and in the left, the left first and second incisors, and a supernumerary first incisor. It would seem as if Nature having a wider space to fill than usual had filled up the gap by supplying this person with an extraordinary number of teeth. Rosenberg,[10] who at the end of the last century collected an enormous amount of literature on the subject, and inspected large collections of skulls, plaster casts of the mouth, etc., considered, in spite of the opinions of Virchow and Busch, that every supernumerary tooth covered with enamel was atavistic. Rosenberg's reading of the condition presented by this case would be the first Incisor, having on its distal surface the second Incisor, and on its mesial surface Incisor *alpha*, and Incisor *gamma* on the distal surface of the second Incisor, on the right side; and on the left, Incisor^1 and Incisor,^{2} with Incisor *beta* in between. The formula would read:

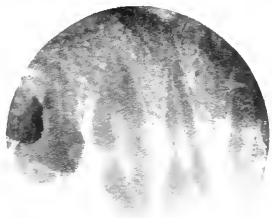
$$\gamma I,\quad {}^2I,\quad {}^1I,\quad \alpha I,\quad I^1,\quad I\beta,\quad I^2.$$

The second maxillary incisors are often undeveloped, although they may have existed in the deciduous dentition. The accompanying radiographs of a boy, aged fifteen years, exemplifies this point (Figs. 43 and 44).

CANINES.—More rarely are the canines absent (not so, however, according to Berten[4]), and more rarely still is there duplication of

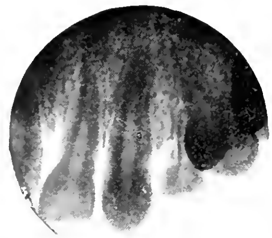
this tooth. A remarkable instance is seen in Figs. 47 and 48, which are radiographs of the jaws of a woman, aged twenty-seven years. The left mandibular canine is absent while the right mandibular tooth, which is only partially erupted, has beneath it and lying horizontally with its crown placed toward the premolars, a second canine.

Fig. 43



Radiograph showing absence of the left maxillary second incisor.

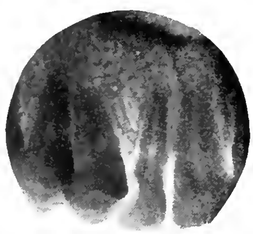
Fig. 44



Radiograph showing absence of the right maxillary second incisor.

Premolars and Molars. — Further illustrations may be given showing absence of the right mandibular second premolar in a girl, aged fourteen years (Fig. 77).

Fig. 45



Radiograph showing absence of left maxillary canine.

Fig. 46

Radiograph showing absence of right maxillary canine.

In Figs. 49 and 50, all four second premolars and the left maxillary second incisor are missing from the jaws of a child, aged between five and six years. Calcification of the third molars has not yet commenced.

For additional examples of anomalous dentitions the reader is referred to the important work of de Terra.[13]

It has been already noted that Man in normal circumstances has thirty-two teeth. The third molar which, as an outcome of racial

evolution acting in a threefold manner to be presently described, is gradually being lost in European, Asiatic, and American races. It is abundantly evident that in those peoples whose teeth are most fully functional the third molars are not only erupted earlier in life than

Fig. 47

Radiograph of the jaws of an adult, aged twenty-seven years. Right side. See also Fig. 48.

elsewhere, but that they reach their highest state of development. Thus, in Mexico this tooth begins to erupt at the age of eighteen, in the mouths of Indians and half-breeds, and this is seldom associated with pathological disturbances, proceeding on purely physiological

lines. Probably the Mexican Indians of Yucatan, Campeachy, etc., with a few African tribes, have the finest teeth in the world.

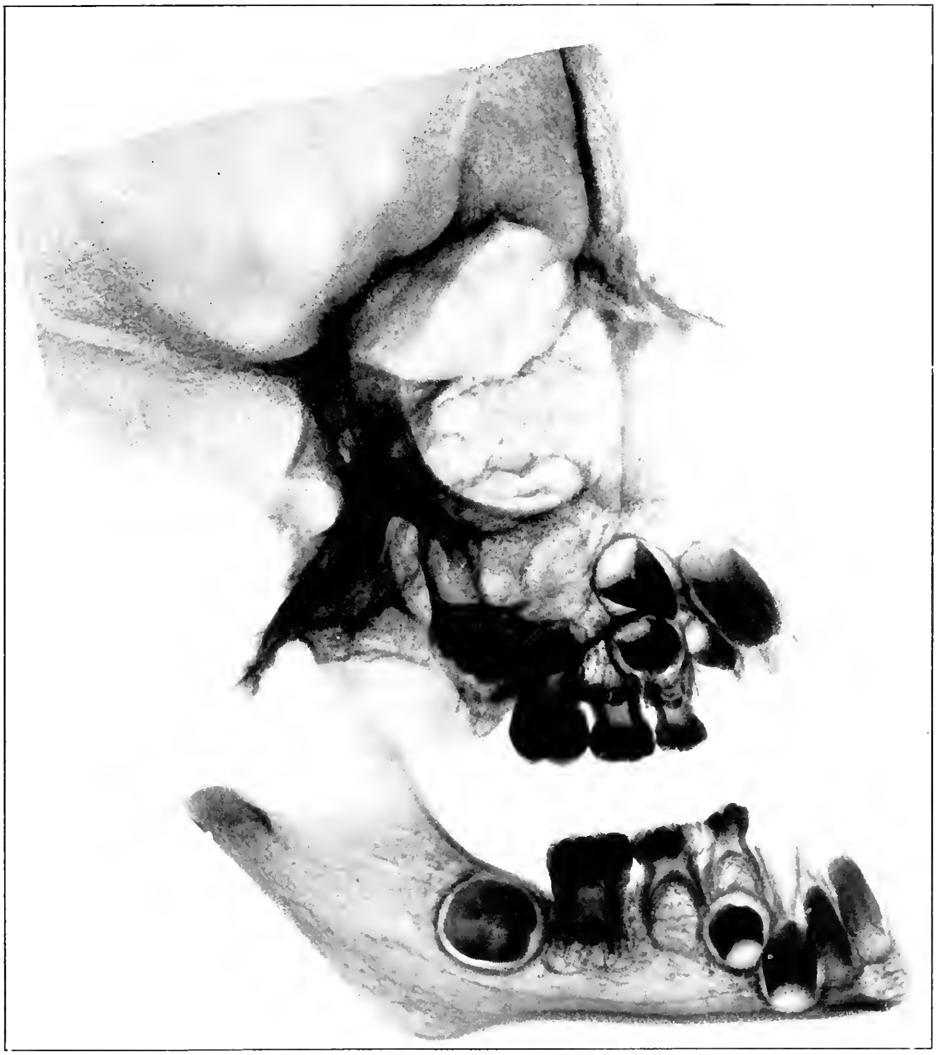
Fig. 48

Radiograph of the jaws of an adult, aged twenty-seven years. Left side. See also Fig. 47.

Factors in the Causation of Numerical Reduction.—The reader is now led to ask: "How is it that Man, *i. e.*, the prehistoric ancestor of Man, has lost from his mouth an incisor and two premolars in each half of his jaws?" The numerical reduction of teeth in the higher

animals is probably due to three important factors, which, all or severally, bring about a reduction in the number. These are probably as follow:

FIG. 49

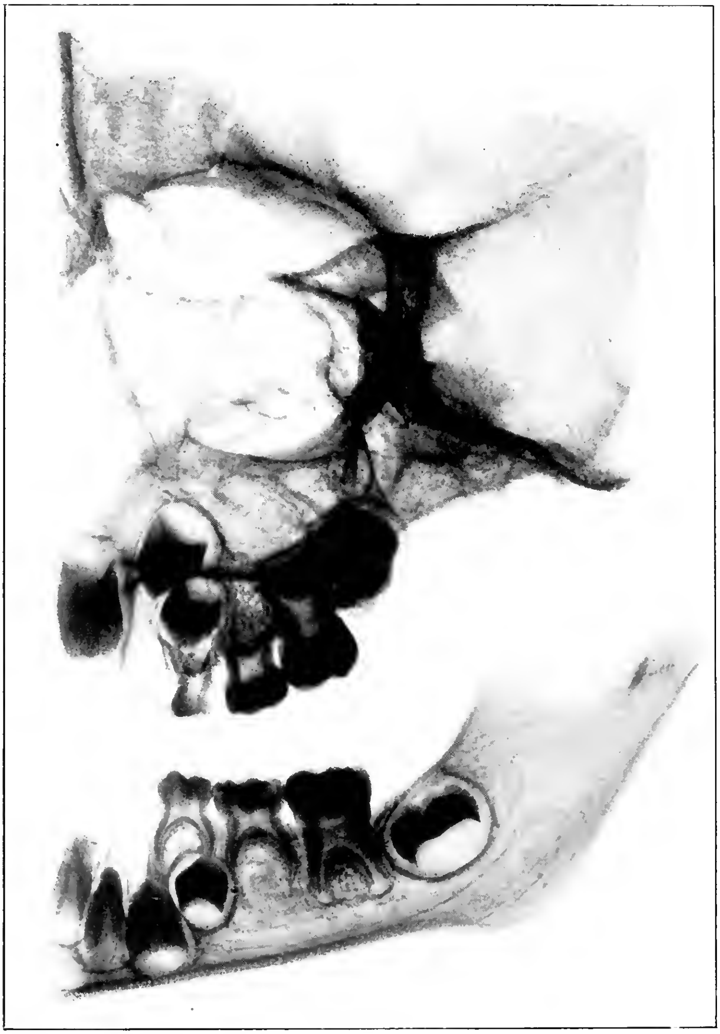


Radiograph of the jaws of a child, aged about six years. Right side. The original in the possession of Mr. W. H. Dolamore.

(1) Incomplete evolution, and, therefore, loss of function of organs. For instance, there is a great tendency at the present day in the mouths

of men for the third molars to disappear. Many people never erupt this tooth. It is an example of an organ which is not required under-

Fig. 50



Radiograph of the jaws of a child, aged about six years. Left side. The original in the possession of Mr. W. H. Dolamore.

going degeneration, and finally almost disappearing. As another, there may be instanced the *Platysma myoides*, and also the vermiform

appendix, which, in Man, is rudimentary, as compared to the same organ in the rabbit. The nictitating membrane of the eye of birds remains today in Man as a mere fold—the *plica semilunaris:*

(2) Progressive enlargement of the more actively functional premolars and molars; for instance, in the cat tribe—*Felidæ*. This probably has been brought about, through their position in the dental arch with regard to the attachment of the very powerful masticating muscles over the zygoma of the jaws. The enormous differences in the size, and shape, and occlusion of the first and fourth premolar in the *Felidæ* is truly remarkable, and probably can only be accounted for in this way, that is, the dynamic forces which act on the bone through exceptionally strong muscular movements, producing very large teeth; and

(3) The shortening of the entire jaw, which increases the power of the bite, but at the same time results in the crowding out of the dental arch of those teeth which can be most readily spared. Comparison of the jaws of the dolphin and of the chimpanzee shows this at once.

Amongst present-day animals, a typical mammalian dentition of forty-four teeth is found in the mole, in the pig, and in the young horse (Fig. 308). In the latter, the first premolar is lost at an early age, but the ordinary adult horse has the whole of the forty teeth.

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CHAPTER IV

THE MORPHOLOGY OF THE TEETH

General Considerations Regarding the Shapes of Teeth.—Examples in Fishes, Reptiles, and Mammals.—Definitions of Individual Teeth.—Reasons for Morphological Variations.—Adaptive Modification as Exemplified in *Trigla and Lophius Piscatorius*, in Viperine Snakes, in Marsupials.—Definitions of Types of Collective Dentitions.

THE FORMS OF TEETH

The next consideration in connexion with this study is concerned with the shapes of the crowns of the teeth. The fishes offer very many different examples; the reptiles and the mammals less. In all, however, these shapes appear to be dependent upon the morphological modifications of (1) a cone, (2) a flat plate, (3) a prism, (4) a cylinder, and (5) a blade or leaf.[3]

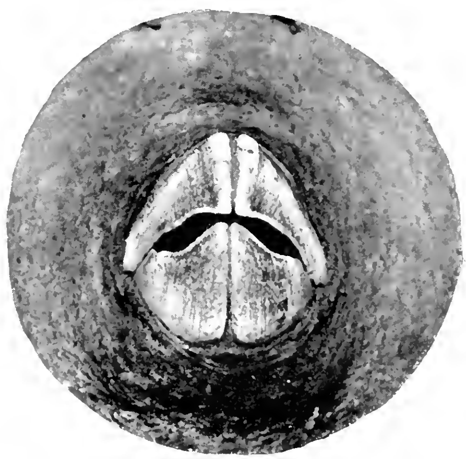
In Fishes.—Examples of all these changes of shape are seen in fishes. Conical teeth may be slender, like a thin rod; sharp; pointed; short; very numerous; closely set side by side, as the *dents en velours* in the perch; equally fine and numerous, but longer and stronger, as the *dents en brosses*, found in the Chætodonts; still larger in size, as the *dents en cardes* of the *Silurus*, or catfish, which, next to the "surgeon-fish," is the largest of all fresh-water European fishes, and possesses on its Palatine bones teeth of all three denominations. In the *Platax*, a species of chætcdont, called the sea-bat, this cone is triplicated at its cutting extremity and becomes shaped like a trident. If the base of the cone is thickened, then the result is conical, similar to the pattern of the teeth of the pike. A short, pointed tooth is found in the wolf-fish (*Anarrhichas lupus*) at the front of the mouth. If the apex of this tooth is flattened, shortened, expanded, and thus made blunter, a cylindrical or hemispherical form ensues, as shown by the posterior teeth of the *Anarrhichas lupus* or the posterior teeth of the *Sargus* (sheep's-head fish) (Fig. 51). It is clear that these fishes

use these teeth for different purposes; the cone-shaped teeth in the front of the mouth for plucking shell-fish, such as limpets, from off the rocks, and the posterior teeth for crushing the shells before extracting the contents. If these posterior teeth are made still flatter, the mouth exhibits on the Pharyngeal bones the effect; and if still further flattened, until the posterior teeth become greatly increased in the transverse and not in the vertical diameter, there result the oblong or square plates, as seen in the extinct *Placodus*. In this way the cone becomes transformed into the plate through the cylinder.

FIG. 51

Jaws of *Sargus*, widely distended to show the incisiform front teeth, and many flat, round teeth used for crushing shell-fish. $\times \frac{4}{5}$.

FIG. 52

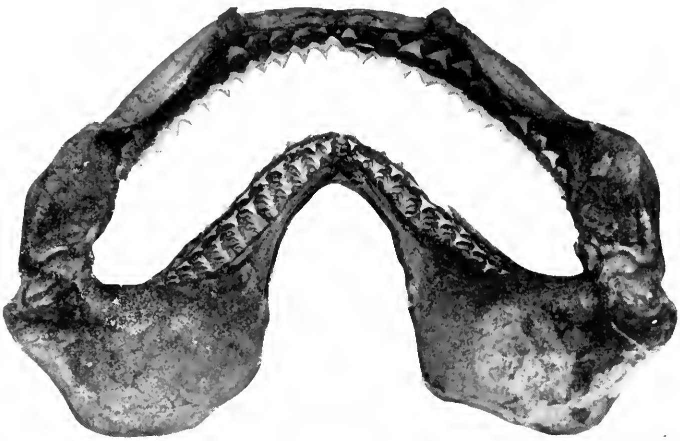


Jaws of a globe-fish (*Tetradon*). $\times \frac{11}{10}$.

Plates may be set horizontally, as just seen, or vertically, as on the Pharyngeal bones of the *Scarus*, or *Pseudo-scarus*, and the beaks of the *Diodon*, or *Tetradon* (Fig. 52). Or they may be extremely numerous and flat, and form a sort of tessellated pavement, as in *Myliobatis* (the eagle-ray), in which they assume a hexagonal or pentagonal shape.

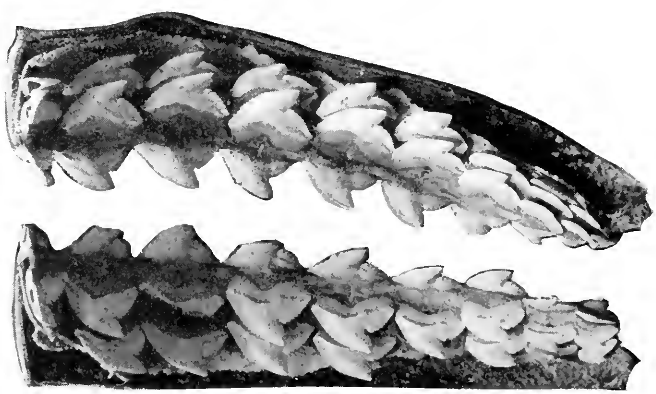
An example of the modification of the prism may be mentioned in the three-sided teeth of *Myliobatis*, a carnivorous fresh-water fish,

FIG. 53



Jaws of a *Lamna* (*Carcharodon*), a carnivorous shark. $\times \frac{1}{10}$. The jaws are widely distended.

FIG. 54



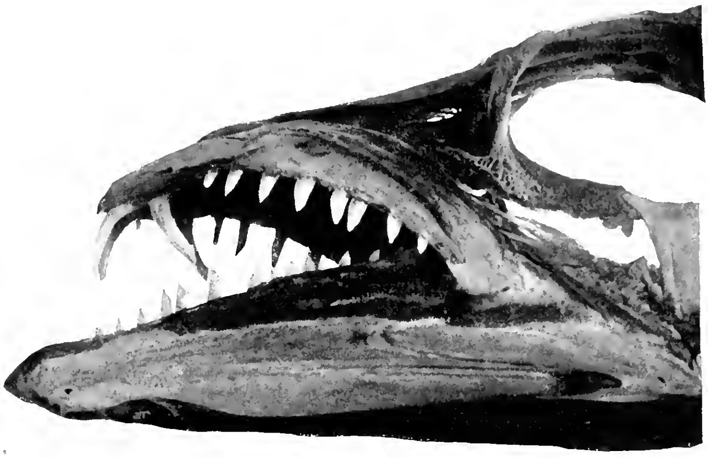
Jaws of the blue shark (*Carcharias*), showing the arrangement and shapes of the teeth. $\times \frac{4}{5}$. The innermost are the oldest and about to be shed.

of Africa and tropical America; in the four-sided teeth of the *Scarus* and, finally, in the six-sided teeth of the *Myliobatis*.

As examples of modifications of the cylinder may be mentioned,

also, the anterior teeth of the *Sargus* and flounder, which have chisel-shaped, incisiform teeth.

FIG. 55



Skull of the carnivorous and predatory hair-tail (*Trichiurus*). × $\frac{1}{1}$.

Blade-shaped teeth are very common in fishes; thus, the simplest is like a lancet, as in the Barricuda pike. If short, small cusps appear, the outline is a little more complicated, a fact well exemplified in *Lamna* (a shark) (Fig. 53); while the edges of the teeth of *Carcharias*

FIG. 56

Skull of a crocodile (*Crocodilus americanus*). × $\frac{1}{10}$.

(Fig. 54) are quite serrated. The higher modification of the blade pattern, which resembles very closely a surgeon's notched lancet, is found in *Trichiurus* (Fig. 55), called the "hair-tail," and in the

Acanthurus, or surgeon-fish. These latter are found in tropical seas. They feed on corals and vegetables, having on each side of their tails a spine like a surgeon's lancet, capable of inflicting a severe wound.

In Reptiles.—These are, as a general rule, simple cones, with curved crown and sharp apex. They are usually oval in transverse section, thick and round in the crocodile (Fig. 56), round and very sharp, as in the snake. In the iguana they are slender, having lobed or serrated apices.

In Mammals.—Simple cones are found, pointed and curved, as in the dolphin. This homodont dentition does not represent a primitive pattern, but a degeneration or retrogression from the typical carnivorous type. Simple flattened cones are seen in the mouths of the

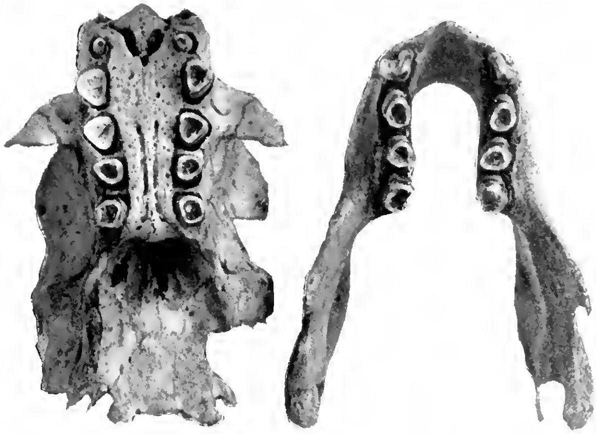
Fig. 57

Skull of an armadillo. × $\frac{1}{3}$.

armadillo (Fig. 57), the three-toed sloth (Fig. 58), and the Cape ant-eater (*Aard-vark*) (Fig. 59). In the two-toed sloth (Fig. 318) the two tusk-like anterior teeth are larger than the rest, for piercing and tearing purposes. In nearly all other orders of the *Mammals*, specialized forms are for special purposes.[1] The cone-shaped teeth in mammals, which are so well seen in the mouth of the dolphin, correspond to the tusks (incisors) of the elephant, and the canines of the walrus and the wild boar; and they are designated "chisel teeth" when applied to the incisors of the rodents.

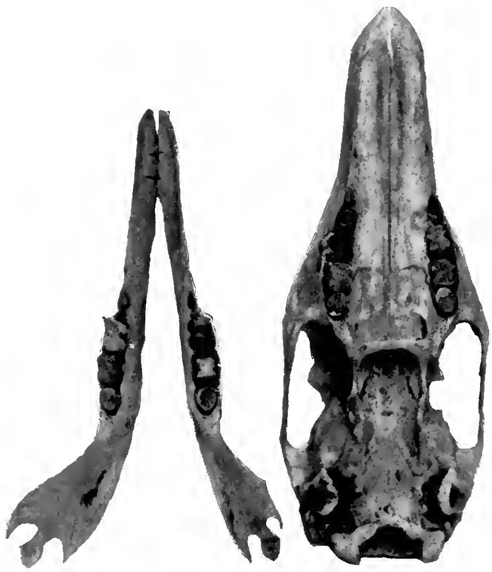
The highest degrees of complexity in shape in mammals are the blade-like "carnassials" of the cat or tiger (Fig. 67). The fourth

FIG. 58



Jaws of the three-toed sloth (*Bradypus tridactylus*) placed side by side to show their relative shapes, lengths, and widths. $\times \frac{3}{4}$. There are five pairs of simple cheek teeth in the upper and four pairs in the lower jaw. *Cf.* Fig. 319.

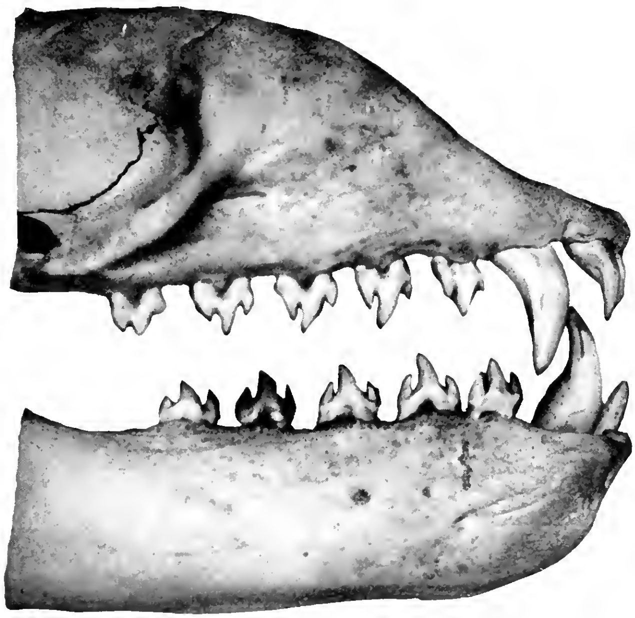
FIG. 59



Jaws of Aard-vark (*Orycteropus capensis*). $\times \frac{1}{3}$. There are four pairs of cheek teeth present. They possess no enamel and are composed of plici-dentine—a unique feature in the *mammalia*. The jaws are placed side by side to show their relative shapes, lengths, and widths.

premolar is the "carnassial" in the maxilla, the first molar is the "carnassial" in the mandible; they vary very remarkably in shape and in size, as will be seen later on. The lower carnassial in the tiger, lion, and cat differs from that of the dog in the fact that it is blade-like, and has no tubercle or heel. A cat does not masticate its food, but a dog does, especially of a soft consistency.

FIG. 60



Jaws of the Antarctic leopard seal (*Stenorhynchus*). $\times \frac{1}{2}$.

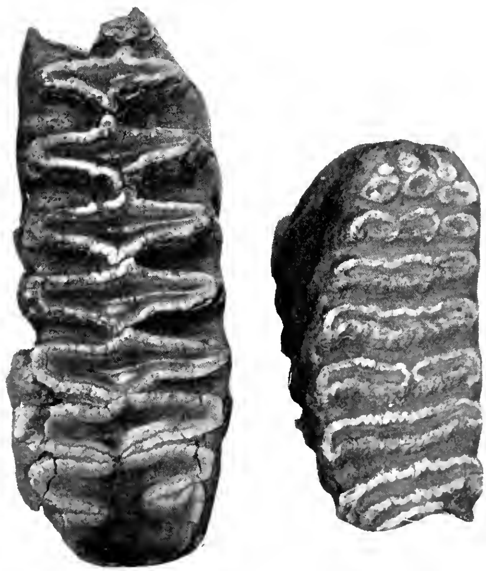
Secondly, another degree of complexity in pattern is seen in the notched teeth of the seal, thus formed for the prehension of slippery, living prey, like fish. This is shown especially well in the leopard seal (Fig. 60).

Thirdly, the molars of the elephant and horse are composed of irregular plates of dentine and enamel, held together by cementum (Fig. 61).

Fourthly, the pectiniform teeth of the *Galeopithecus*—for the purpose of combing its fur. And lastly, the ptychodont dentitions of hares and rabbits afford further examples of diversity in form of crown.

A cingulum is found in some of the *Carnivora*, and is well developed in animals like the hyæna (Fig. 62), as well as in insectivorous types of teeth. It is an enlargement of the cervical parts of the teeth, and its function is to protect the gum margin from injury by splinters of bone or hard substances. The food of the hyæna is generally dead animals and carrion, and by means of its dental cingula it is enabled to crunch up bones without doing any harm to the gums and root membranes of the teeth.

FIG. 61



A *B*

Coronal aspect of molars of (*A*) African and (*B*) Indian elephant. $\times \frac{1}{2}$.

It is probably the absence of the cingula in the premolars and molars of the horse which accounts for the prevalence of certain forms of dental periostitis which is common when this animal is in a domesticated state, for small pieces of chopped hay, blades of grass, stalks of corn, etc., can easily penetrate the gum margins of these cheek teeth.

Definitions.—It is now necessary to distinguish between the various kinds of teeth found in the mouth of Man and Mammals generally. The following definitions supply the present needs of the reader:

The upper *Incisors* are teeth implanted on the Premaxillary bone; the lower incisors are, in occlusion, the corresponding teeth.

The upper *Canine* is that tooth implanted in the maxillary bone, which is placed immediately behind the premaxillary suture. The lower canine is the tooth in the Mandible which closes in front of the upper. In animals such as the ox, the giraffe, etc., where there are no maxillary incisors or canines which could be used as a guide, the fourth tooth from the symphysis of the Mandible is the canine,

Fig. 62

Skull of a hyæna. × $\frac{1}{3}$. *Cf.* Fig. 260. The first right maxillary premolar is missing and the first maxillary molars are invisible in this photograph.

although it may closely resemble an incisor. It is a canine because it erupts much later than the other three, and because mammals have no fourth incisor except the polyprotodont marsupials.

The *Premolars* are those teeth in front of the molars which, in typical diphyodonts, replace deciduous predecessors.

The permanent *Molars* are teeth at the back of the mouth which erupt behind the "milk" teeth and have no predecessors. The deciduous molars are those which are replaced by the premolars.

REASONS FOR MORPHOLOGICAL VARIATIONS

Having already seen how diversified are the shapes of the teeth, the next consideration must be: "What has brought about these variations in dental shape and pattern?" It is difficult to answer this question very satisfactorily. At all events, two theories may be mentioned, which perhaps throw some light upon the question.

Inheritance.—Inheritance, or following an original pattern or model, or type, was for many years the accepted theory as to the cause of these morphological variations. This was known for generations as the Archetype Theory.[6]

Adaptive Modification.—But there is a newer, and more scientific explanation in connection with the matter, *viz.*, that certain progressive, slow modifications from few and simple forms, in which disused organs deteriorate and much used organs develop, have produced, in the course of ages, these mutations in shape. This theory of Adaptive Modification of organs is probably correct. As an example of disused organs degenerating, in addition to those before mentioned, it is interesting to note that the rudimentary condition of the eyes of the *Amblyopsis*—a bony fish found in the water in the depths of certain caves in Kentucky—is probably produced by the darkness of their subterranean dwellings. The intense lack of light in these huge caves is of no use to these fishes for the purposes of getting their food. Their eyes are not wanted for visual purposes, and they have, in the course of evolution, degenerated.

It has been shown experimentally that it is possible to create artificially this loss of sight. Professor Thomson, the Regius Professor of Natural History in the University of Aberdeen, draws attention, in "Knowledge," 1912, to some observations made by Mr. Ogneff in this direction. Goldfish were kept in absolute darkness for a period of over three years, in aquaria with an abundance of food. The structure of the pigment epithelium of the eyes became completely altered, and the rods and cones of the retina disappeared. The fish became totally blind. Other pigment and structural alterations simultaneously occurred. At the end of the first twelve months the fish had

become black; but after the second year they assumed their golden appearance again, the reasons apparently being that the black color-matter was produced by the superficial extension of dark pigment cells, which were, in time, absorbed by certain phagocytes, resulting in the re-exposure of the golden cells of the deeper layer.

Certain deep-sea fish in the Indian Ocean are blind, or nearly so. To compensate for the dimness of the sense of sight, many have curious and interesting antennæ largely developed on their heads for tactile purposes, thus assisting in the capture of their prey. It has already been shown that the Gangetic dolphin, which is practically blind, has an enormous number of teeth.

Fig. 63

A *Trigla*, showing at *A* the three jointless limbs of the anterior portions of the pectoral fins. × ½.

Examples of Adaptive Modification. — Certain examples of Adaptive Modification of individual organs may be noted: The *Trigla* (Fig. 63), a gurnard (the *rouget* of the French), has the anterior portion of its pectoral fins adaptively modified into three jointless tentacles, which serve the purposes of locomotion. By means of these ray-like appendages the fish is enabled not only to walk on the surface of the floor of the sea, but also to use them as tactile organs, in the same way as the antennæ in the deep-sea fish in the Indian Ocean. According to Günther,[2] this sense of touch in the tentacles of the *Trigla* is very highly developed, the *medulla oblongata* being specially bulbous to provide an efficient nervous mechanism for the control of the tactile sense.

Another excellent example of adaptive modification of fins is seen in the angler fish, or *Lophius piscatorius*. This fish lives in the mud, a lazy life. The anterior portion of the dorsal spine has been converted into a long, stiff, bristle-like tentacle, somewhat like the end of a fishing rod. This similitude is heightened also by its position, at the extremity, of a little bushy mass, which closely resembles the

bait of a fisherman. The fish lies in wait for its prey, which, swimming overhead, sees an imaginary bait at the end of a fishing rod. On grasping it, the huge mouth of the sea-angler is opened, and the prey is easily engulfed.[2]

But perhaps even more striking still are the variations of the teeth of snakes. The python (Fig. 64), which is a harmless snake—that is to say, does not kill its prey by poison, but by compression in the coils of its body—has two upper rows of teeth—an outer, on the Premaxillary and Maxillary bones, and an inner, on the Palatine and Pterygoid bones. It has, also, of course, teeth on the mandible. The vipers, on the other hand, represent the class of poisonous snakes. They have enormously developed poison fangs, the rest

FIG. 64

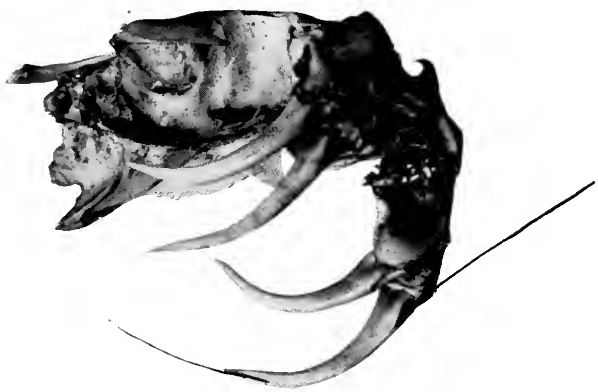
Jaws of a python. $\times \frac{2}{3}$.

of the maxillary teeth being lost, or nearly lost, and the bones of the skull at the same time greatly shortened in the antero-posterior direction. The vipers kill their prey by injecting poison into their bodies. Intermediate between the pythons and the vipers are naturally placed the Colubrines, which are classified as *Aglypha*, which are harmless, and have no notched teeth—exemplified in the common English snake; secondly, the *Opisthoglypha colubrines*, where the back teeth are grooved and not very poisonous; and, finally, the *Proteroglypha colubrines*, where every one is a poisonous snake. The solid teeth are reduced in number, those on the Maxillary bone are diminished, and the front teeth, considerably longer and larger than those behind, having become grooved, are used as poison fangs. Thus, in the

evolution of the poison fangs of snakes, and as the result of the adaptive modification of organs collectively, are found examples of open-grooved poison fangs, close-grooved poison fangs, and complete poison fangs.

The method of erection of the poison fang in the viperine snakes is as follows: The digastric muscle, on contraction, draws up the Mandible, which, acting on the lower end of the Quadrate bone, pushes it in a forward direction. This bone, articulating with the Pterygoid and Palatine, which are similarly pushed forward, tilts the Transverse bone from a horizontal into a vertical position, and at the same time, with its articulation of the Maxillary bone, causes the latter to

FIG. 65



Poison fangs of a viper, with a bristle passing through one of the canals. × $\frac{1}{1}$.

move downwards and forwards, instead of backwards, as in the closed condition of the mouth. The poison fang, being attached securely to the Maxillary bone, instead of lying flat on the palate, now assumes a vertical position. The whole of the method of the erection of the poison fang is a beautiful adaptation by Nature to prevent the loss of this important organ amongst the poisonous snakes (Fig. 65).

Finally, another example of adaptive modification of collective organs may be found in the dentition of the kangaroo (Fig. 66). It has been discovered in this, and in other marsupial animals, that the imperfect fœtuses are not expelled from the uterus, as in placental mammals, because the whole group of animals inhabiting the Australian

continent, apart from those artificially introduced by Man, are implacental, that is, they do not possess placentæ. But the nude larvæ pass through a tube from the uterus to the maternal pouch, where they get attached, as shapeless masses, no bigger than the thumb, to the mammary teats in the pouch. Here they remain a long time, their nourishment being provided by the contraction of the abdominal muscles upon the breasts, which action supplies abundant milk diet. Nature has arranged a modification in the conformation of the oral and nasal cavities, so that the act of feeding the young will not stifle them, by preventing them from breathing. Thus the marsupial animals do not require any teeth while they are in the young condition.

FIG. 66

Skull of the kangaroo (*Macropus rufus*). × ½. *Cf.* Fig. 320.

Have kangaroos any milk teeth? Probably not, because they are not wanted. A German writer, Leche,[4] found some rudimentary calcified teeth in sections which he made of the jaws on the labial side of the functional tooth germs; but two Australian observers—Wilson and Hill[7]—believe that these germs are those of ordinary milk teeth, which have been suppressed because of disuse. Dr. Marett Tims considers that the upper first premolar, which apparently is lost early in the marsupials and is the only tooth which might perhaps be called a deciduous tooth, is probably not a milk tooth at all, but belongs to the same dental series which persists throughout the life of the animal. Recent examinations of specimens confirm this view.[3] Its situation above the first molar in the upper jaw is probably due to the

kinking or folding of the tooth band in the fœtal state. Thus it is probable that in the jaws of these animals the dentitions have become adaptively modified to the requirements of the creatures generally, and further that they exist in the most diversified forms, adapted to different modes of life.

As living depends upon eating, and eating depends upon the efficiency of the teeth, it is not surprising to learn that all kinds of dentitions are found amongst the marsupial animals.

There are examples of the carnivorous type in the thylacines, whose dental formula is $I\,\frac{4}{3}\ C\,\frac{1}{1}\ Pm\,\frac{3}{3}\ M\,\frac{4}{4}$; the herbivorous type, as in the kangaroo, in which the formula is $I\,\frac{3}{1}\ C\,\frac{0}{0}\ Pm\,\frac{1}{1}\ M\,\frac{4}{4}$; the insectivorous type, as seen in the *Myrmecobius*, in which the formula is $I\,\frac{4}{3}\ C\,\frac{1}{1}\ Pm\,\frac{3}{3}\ M\,\frac{6}{6}$. There are also rodent-like marsupials, as exemplified in the wombat, in which the formula is $I\,\frac{1}{1}\ C\,\frac{0}{0}\ Pm\,\frac{1}{1}\ M\,\frac{4}{4}$; honey-eaters as the tarsipes and the arboreal leaf-feeder, the *Koala*.

TYPES OF DENTITIONS

Definitions.—The distinguishing characteristics of these different types of dentition must now be noticed.

Carnivorous, *i. e.*, flesh-feeders. (1) There are six incisors in a straight line—rather small teeth. These are used for scraping the muscles and their attachments off bones. (2) The canines are large and very prominent; they are used for wounding prey or seizing it, and for other prehensile purposes. (3) The premolars are like blades, small in front, and very much larger behind. They are used for sectorial purposes, very much in the same way as scissors. (4) Carnassials are present, namely, the upper fourth premolar and the first lower molar. (5) The molars are small in size and reduced in number. In the *Felidæ*, for instance, which are typical carnivorous animals, the molar is a tiny mound placed behind and to the inside of the posterior surface of the huge fourth premolar. The lower permanent molar, however, is a large tooth, and to the casual observer appears as if it were a premolar. It is not a premolar, however, because of its development. It has never had a deciduous predecessor, and it has erupted

behind the other premolars. The upper molar in the *Felidæ* is probably functionless, but it is believed that the dog uses it for chewing leaves of grass. (6) There is a broad short dental arch. (7) The temporo-mandibular articulation exhibits a true example of a ginglymus or hinged joint, the condyle being transverse (Fig. 67).

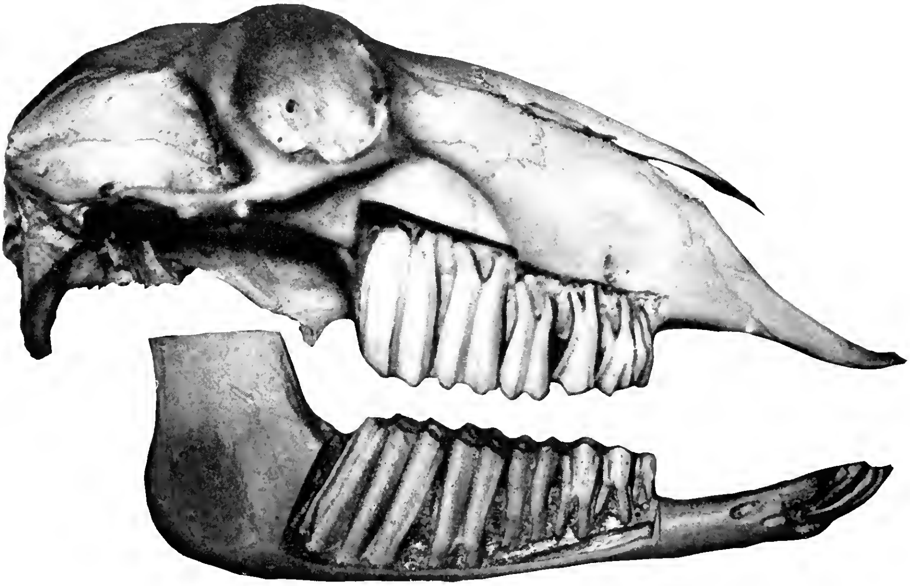
FIG. 67

The carnivorous type of dentition. × $\frac{1}{6}$. Skull of a lion (*Felis leo*).

HERBIVOROUS, *i. e.*, vegetable-eaters. (1) There are few incisors; the rule is that there are no maxillary incisors, their place being occupied by a thick pad of gum. (2) The canines are rudimentary or absent, unless they are used, as has already been pointed out, as sexual weapons, as in the wild boar and in the musk deer. (3) The premolars are well developed; usually about three or four in number. (4) There are no carnassials. (5) The molars are large in size and normal in number. They are hypsodont, that is, possess tall crowns. This is true in some classes of herbivorous animals, namely, those which graze, like the antelope, the sheep, the ox, etc., which eat grass and corn. Here it is obvious that strong, tall teeth will be necessary to stand the wear and tear on account of the nature of their food. But the other herbivorous animals, like the giraffe, for instance, which merely browse, and do not require to do such hard work of mastication as grass requires, have simply blunt (bunodont) cheek teeth. Sheep eat grass and corn,

deer eat grass and leaves—they graze; the giraffe browses, eating leaves only. It uses its lower incisors for twisting off from the tree or from the ground the leaves and grass on which it feeds. (6) There is a long, narrow dental arch. (7) The condyle is globular, which allows of free lateral movements of the mandible (Fig. 68).

FIG. 68



The herbivorous type of dentition. Skull of a hornless sheep. × ½. The external alveolar plates have been removed to show the sizes, shapes, and positions of the roots of the selenodont teeth.

FIG. 69

The insectivorous type of dentition. × 1/1.

INSECTIVOROUS, *i. e.*, insect-eaters. (1) There are not less than two pairs of incisors in the mandible, of which the first pair is often larger than the others. They are not chisel-shaped. (2) The canines generally are not larger than the other teeth, except in the mole. (3) The premolars have many cusps. (4) The molars have many sharp cusps either

arranged in the form of a V or of a W, to enable the possessor to crunch up the chitinous envelopes of the bodies of their prey. (5) The skulls are small in size (Fig. 69).

Fig. 70

Lingual aspects of the jaws of an adult man, showing the normal arrangement of the permanent teeth in the dental arches. × 1/1. An example of a typical omnivorous dentition. The premolars are, clinically, the first and second, but, anatomically, they are the third and fourth of the typical mammalian dentition.

As an example of mixed type of dentition Man is

OMNIVOROUS (Fig. 70). The pig also is omnivorous. In the pig and the wild boar the canines are large and powerful, for digging up roots; the lower incisors are procumbent, that is, placed in a horizontal instead of a vertical position, for grubbing in the ground. The anterior cheek teeth are used for breaking up and dividing into pieces the food, while the molars crush it and masticate it; but as mastication of matter is not so essential in pigs as in the ruminants and other grass and leaf-eating animals, the molars in the pigs have low, blunt (brachyodont) crowns.[5]

Thus, in conclusion, we find that the cone and its modifications are used, amongst other purposes, for combat, for seizing prey, or killing it by injection of poison; the cylinder and its modifications for combat; the prism or plate for crushing food; and the blade-shaped tooth for tearing or cutting up food into small pieces; and that animals' teeth have been, in the course of evolution, adaptively modified to serve these different functions.

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CHAPTER V

DARWINIANA

The Origin of Variations of Species.—History.—The Theories of Linnaeus, Cuvier, Lamarck, Goethe, Darwin.—Natural Selection.—Sexual Selection.—Dental Variations.—Atypical Dental Heredity.—Evidences of the Mutability of Species.—Proofs of Derivation of Species.—Post-Darwinian Theories.—The Mutation Theory.—Mendelism.

ORIGIN OF VARIATIONS OF SPECIES

Introductory.—Having now noted the differences existing in several types of the dentitions of animals—Insectivorous, Carnivorous, Herbivorous, etc.—and having seen that the Adaptive Modification of organs plays a great part in producing variations in the shape, size, and number of the teeth, as evidenced in the poisonous fangs of snakes, etc., it is quite clear that variations in animals are extremely common, and their species too are very numerous. It is probable, however, that all had a common origin. A cell or tiny organism is capable of becoming an elephant or a frog, a crocodile or an ape. Why is this? In other words: "How have variations which have resulted in the formation of millions of species of animals, insects, and plants arisen?" The answer is to be found in Darwin's works. The same rules which apply to variation in animals apply also, more or less, to teeth, and it is necessary, in order to understand the operative forces which have produced these variations of teeth, to have a superficial knowledge, at all events, of the work of Charles Darwin. For it is clear that there are three great agencies, apart from possible others, which seem to influence the varying shapes of animals and their teeth, namely: (1) a Natural selection or Survival of the fittest; (2) Sexual selection; and (3) Concomitant variation or Correlation of growth, *i. e.*, that obscure agency which affecting one part or organ of the body may secondarily occasion alteration in other parts or organs of the body.

Historical.—As a preliminary to a short outline of the Darwinian theory of evolution, it will be convenient to remember the historical

aspect of the question. It must be already predicated that the subject is very vast, and abstruse, and difficult to crystallize into a few pages.

In 1735 Linnaeus[11] (born in 1707, died in 1778) was the first to classify and name various groups of animals and plants. He believed in the Mosaic story as recorded in the Bible, that is, in the Creation, in the Beginning, of one pair of each species of animals and plants. But the science of palæontology was unknown to him. Men had not at that time begun to find in the earth fossil remains of prehistoric animals and plants.

Cuvier, the great naturalist, at the beginning of the Nineteenth Century (1769–1832), held that, as the surface of the earth revealed many fossilized bones of varying size and character, there must have been several Deluges, and not one, as recorded in the Book of Genesis, and that after each catastrophe a fresh creation of living things occurred throughout the natural world. This was the Catastrophic Theory, and it was believed in for about fifty years, till Lamarck and Lyell proved that the theory was wrong.[14]

Lamarck,[9] the French zoölogist (born in 1744, died in 1829), tried to show the real cause of the origin of species, and was the first who proposed any detailed scientific theory of the origin of the various species of organisms by a natural process of modification. He held that there were no essential differences between living and lifeless beings, Nature being one united system of phenomena. Thus he controverted Cuvier's theory. "All the different kinds of animals and plants which we see today," he wrote, "or that have ever lived, have descended in a natural way from earlier and different species. All come from one common stock or from a few common ancestors of the lowest type, arising by spontaneous generation in organic matter. Succeeding species have been constantly modified by adaptation to their varying environments (especially by use and habit), and have transmitted their modifications to their successors by heredity."[10] By "spontaneous generation," or abiogenesis, is implied the theoretical doctrine that living matter may be produced by not living matter, a view supported largely by Bastian, Ponchet, and Haeckel. Thus, if the conditions are favourable, many organisms of a low type will make their appearance in infusions of dead material from which all extraneous

micro-organisms are excluded. The simple experiment of putting a handful of dead hay into water proved conclusively to the minds of these earlier investigators the fact that millions of bacteria could and did become generated, in due time, merely from the presence of the hay in water. No conclusive proof has been obtained of the occurrence of abiogenesis.[19]

Lamarck first formulated the conclusion that man descended from the ape, explaining this by applying to his theory the testimony of those agencies which brought about the natural origin of plants and animal species. These agencies are two in number: (1) Adaptation, by means of use and habit, and (2) Heredity. Examples of these may be given, as the long tongue of the humming-bird and the woodpecker—organs which were adaptively modified to serve the purposes of these birds. The neck of the giraffe and the web of the frog's foot exemplified a similar principle.

The Lamarckian theory was, in brief, that every part or organ of a creature used in satisfying its wants was increased in size or strength or otherwise modified by use and effort, and that the modifications or variations produced in these ways were transmitted to its progeny, and thus led, in the course of generations, to the production of the various forms which are seen everywhere in the natural world. As an example, it may be mentioned that the ancestor of the beaver or the frog was not web-footed in order that it might swim, but its wants having attracted it to a stream of water in search of food, it extended the toes of its feet in order to strike the surface of the pool and move more rapidly upon it. Thus, in course of time were produced the broad membranes which now connect the toes and make it web-footed. Present-day Neo-Lamarckians (*i. e.*, those who still hold the Lamarckian views) have amongst their number Professor Cope, of America (see Chapter VIII), whose investigations, however, dealt exclusively with extinct creatures, and avoided any attempt to account for the phenomena in living beings.

That the use or disuse of organs was a very important factor in organic development is clear, but it is not sufficient to explain the origin of species. Lamarck, however, failed to discover the principle which Darwin afterward found to be the chief agent in the theory

of transformation, namely, the principle of Natural Selection in the struggle for existence.

Natural Selection.—Natural selection may be defined as: The survival of the fittest in the struggle for existence; the agency by which variations, beneficial to their possessors, will be preserved and intensified in successive generations. The doctrine underlying the Darwinian theory is applicable to the teeth, which are brought up to their highest state of efficiency, as exemplified, for instance, in the incisors of the wombat in Australia, the aye-aye in Madagascar, and rodents generally.

But another man was the first forerunner of Darwin, though he never formulated evolution as a scientific system like Lamarck—Goethe, the great German poet. In 1807 he wrote, in an "Essay on the Metamorphoses of Plants," "When we compare plants and animals in their most rudimentary forms, it is almost impossible to distinguish between them." He named two forces: (1) A Centripetal force, which maintains the standard of the specific forms in the succession of generations, that is, heredity; and (2) a Centrifugal force, which is constantly modifying species by changing their environment, that is, the adaptative modification of organs.

Then Darwin appeared. He was born in 1809 and died in 1882. His successful theory was based on a mechanical explanation of this modification of plant and animal structure, by adaptation and heredity. He compared the origin of the various kinds of animals and plants which are today modified by artificial breeding by Man with the origin of the species of plants and animals in their natural state.

The essentials of the Darwinian theory are threefold:

I. Man has made his domestic breeds of animals and plants by the selection—conscious or unconscious—of very slight or greater variations.

II. The material for selection exists in Nature, *viz.*, the slight variations of all parts of the organism.

III. The "unerring power" which sifts these variations is *Natural Selection* . . . which selects exclusively for the good of each organic being. In short, in the struggle for existence "favourable variations would tend to be preserved, and unfavourable ones to be destroyed. The result of this would be the formation of new species."

The struggle for existence produced new species without premeditative design in the life of Nature, in the same way that the will of Man consciously selects new races under artificial conditions. For instance, the horticulturist of today can produce new species of fruit or flower at will. It is possible to produce a blue primrose and a black hyacinth. The pigeon fancier, the horse and dog breeder are able, almost at will, to produce new forms of bird or quadruped. In the natural state the struggle for life is always unconsciously modifying the various species of living things. This struggle for life, or competition of organisms in securing the means of subsistence, acts without any conscious design, but it is none the less powerful in modifying structures. As heredity and adaptation enter into the closest action under its influence, new structures or alterations of structures are produced.

This is the central thought of Darwinism, but as yet, Darwin had no idea of applying these principles to Man. He believed that Man held a special position in the universe.

A small book, entitled "The Evidence as to Man's Place in Nature," was published in 1863, by Thomas Huxley. In it, he applied to Man the Darwinian theory, and eight years later, Darwin's "Descent of Man" was printed. The latter author drew the conclusion that Man also must have been developed from lower species, and he described the important part played by Sexual selection in the evolution of *Homo* and the other higher animals.

Sexual Selection.—Sexual selection may be defined as: The agency which operates principally by enabling those possessed of certain characteristics to propagate their race, while less favoured ones do not get the opportunity of doing so. For this end the males of some species are very much ornamented. The males of birds sing; many male animals possess teeth which females have not—like the musk deer, the muntjac, and the narwhal. The males choose the handsomest females in one class of animals, and the females choose only the finest looking males, and so on. These sexual features are increasingly accentuated. It is to this that we owe the family life, which is the chief foundation of civilization. The rise of the human race is largely due to the advanced sexual selection which our ancestors exercised

in choosing their mates. It is possible that sexual selection tends to prevent irregularities in the position of the human teeth.

Living organisms have a very complicated structure, inherit certain tendencies, and by their movements and mobility are capable of undergoing countless variations. Variations are brought about by the environment of the organism on which life depends. When the environment of an animal or a person changes, the organism either adapts itself to that change, or does not adapt itself to that change. If the former, it lives and varies in greater or less degree; if the latter, it dies.

Fig. 71

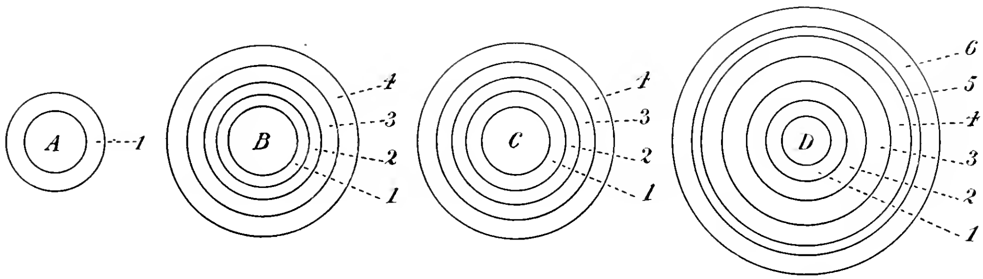


Diagram illustrating "correspondence with environment:" *A*, a medusa; 1, the sea. *B*, an oak; 1, the earth; 2, the air; 3, the rain; 4, the sunshine. *C*, a lark; 1, the light; 2, the food; 3, music; 4, love of freedom. *D*, a man; 1, the air; 2, the food; 3, the home; 4, religion; 5, eugenics; 6, the Arabic language, etc.

What is life? Life may be philosophically defined as Complete correspondence with environment. What is death? Death is the converse of this, that is, Incomplete or Imperfect correspondence with environment. A few illustrations will make this clear (Fig. 71). A jelly fish is alive when it is in the sea, that is, when it is in complete correspondence with its surroundings; but it dies when cast up by the sea waves on to the shore, because then its environment is incomplete —or it is in incomplete correspondence with its environment—and because it cannot adapt itself to that external change.[6]

Further, the oak lives because it is in complete correspondence with its environment, namely, the ground, the air, the sky, the rain, the sunshine; but let it be deprived of one or more of these—for instance, if its roots are pulled up—it will die, because it is not in complete correspondence with its environment.

A bird, like the lark, has a bigger life than the oak, because into its short existence there come the affections of home, the love of music, the delight of freedom, and so on; and as long as it is in complete accord with this higher environment, it lives. Even when caged it may continue to exist, because it is able, more or less, to adapt itself to the artificial conditions in which it finds itself.

Man, too, is encompassed by numberless forms of environment. As long as he adapts himself to these, and is in perfect correspondence with them, he lives; but unless he is in perfect correspondence with them, he dies, or is dead to them. Thus, a knowledge of the Arabic language may be an environment of a certain man; but one who knows not a word of that language is dead to that environment.

An interesting example may be added to the above. The common English ring snake is oviparous in its natural state in the fields. When kept in a cage in captivity, without sand, however, it becomes viviparous.

Variations in Teeth.—Bateson,[1] during recent years, has collected an enormous amount of material for the study of variation, and has very thoroughly investigated the bearing of it as it affects the teeth of the vertebrates. This occupies an important place in his scheme of dealing with a very abstruse subject. The association of "diverse phenomena which are commonly treated as distinct," has led to the creation of the word "Merism," which means the phenomenon of the repetition of parts generally occurring in such a way as to form a symmetry or pattern. This study of variation is complicated by the occurrence of qualitative, in addition to simply numerical changes.

The principles which underlie the facts would appear to controvert the doctrine that the domestication of animals induces or causes variation, when variation in wild animals is taken into consideration; would show that very frequently dental variation is asymmetrical; that increase in the number of the teeth has arisen from dichotomy or division of a simple tooth germ; that the teeth placed at the ends of series are liable to undergo great numerical variation; and that there is a fairly constant relation between the size of extra teeth, and that of the teeth next to which they stand, so that the new ones are, as it were, from the first, of a size and development suitable to their position.

In the man-like apes (*Simiidæ*), Bateson found and marked numerical and topographical variations. There were examples of supernumerary molars (see Fig. 85), and incisors and malposition of premolars; in the old-world monkeys supernumerary incisors, molars, and premolars, and absence of molars. In the carnivores the addition and absence of incisors were noted, dichotomy appearing in a bull-dog. The numbers of premolars were increased and diminished, and in the molar regions were added to. Meristic variability in the incisors, premolars, and molars occurred in cats, wild-cats, martens, otters, seals; supernumerary incisors were observed in the horse, and many abnormal forms in sheep and marsupials. Meristic variation exists occasionally in the dentition of the sharks and rays.

Atypical Dental Heredity.—The influences of heredity are also frequently met with in connexion with the jaws and teeth. Mr. J. G. Turner[16] has assembled some cases in which are described the results of its operations, producing topographical irregularity of teeth and even of the genesis of supernumerary teeth; and leaving evidences in the altered character of the jaws, when the large teeth of one parent and the small jaws of the other are inherited. The Royal family of the Hapsburgs furnishes a remarkable instance of hereditary epharmosis.

The absence of teeth and the endowment of a conical pattern of crown—atavism—are often inherited. Again, the acquired peculiarities of one or more teeth may be transmitted to progeny. The maxillary second incisor is frequently missing, and cases have been recorded where hereditary reduction in the numbers of the teeth and their characteristics have been associated with abnormal conditions of the hair, skin, and eyes. Changes in the structure of teeth, also, have been noted. (See Appendix, Note A.)

Thus, the transmission of variations of parental form and structure to offspring comprises stages in the development of different life forms. In short, likenesses are inherited, variations are acquired, and are, in spite of Weissmann, capable of being transmitted to progeny. Weissmann experimented in this matter, and he came to the conclusion that acquired characteristics cannot be transmitted to progeny. His classical experiment consisted of amputating the tails of great numbers of generations of mice, to try and prove that in the course of

time the progeny of such mutilated animals would be born with short tails. He did not succeed, however. The probable reason was that the attempt to bring about the evolution of the short tail was too sudden.

EVIDENCES OF THE MUTABILITY OF SPECIES

It is necessary to add a summary of the evidence of the mutability of species.[2]

(1) Every individual of the same species, that is, groups of individuals which possess characteristics in common, tends to vary. There are no two people or individuals exactly alike; there are no two people or children of the same parents, no two sheep, no two hyacinth bulbs, no two blades of grass, no two finger prints, which possess identical characteristics. This tendency to vary is produced by changes of the environment of plant or animal; for instance, the snake, as just mentioned.

(2) These variations are capable of being transmitted from parent to offspring; they, therefore, tend to become permanent.

(3) New varieties of plants and animals are produced by Man artificially, by his taking advantage of these transmitted variations. Illustrations may be given by mentioning that all classes of pigeons—the pouter, the tumbler, the fantail, the carrier, etc.—are derived from the blue rock pigeon of the coasts.

All varieties of dogs—the bulldog, the pug, the hound, the retriever, the mastiff, the fox-terrier, etc.—are said to come from the Indian wolf.

Professor Jeitteles, of Vienna, first suggested this theory in 1877. It is concluded that the dog is of the East, coming from India when that country was undergoing "glaciation." The evidence that the Indian wolf had some part in the origination of our dogs is very great, but scientists generally hold that Darwin's[5] evidence for a plural ancestry is overwhelmingly greater, although he most carefully points out that "We shall probably never be able to ascertain their origin with certainty" (vol. i, p. 17).

All varieties of horses—the race-horse, the cart-horse, the Shetland pony—owe their origin to the wild-horse.

All the varieties of apples seen on a green-grocer's stall claim the ancestry of the common sour crab apple. The recent experiments of Burbank, of America, have tended to produce fresh variations in the growth, colour, and flavour of fruits and vegetables—potatoes, the tubers of which grow above the ground, fruits possessing the combinations of the qualities and flavours of plums and apricots, and so on.

It was Darwin who showed that Nature does, on a large scale, during countless ages, and through countless generations, what Man can do artificially within a limited range of time. This is Natural Selection.

(4) More organisms are born than survive. "There is no exception to the rule that every organic being naturally increases at so high a rate that, if not destroyed, the earth would soon be covered by the progeny of a single pair." If all the offspring of a pair of elephants that lived seven hundred and fifty years ago had survived, there would be today nineteen million elephants in the world. One common house fly produces in its fifth generation at the end of eight weeks, twenty-six million flies! Instances might be multiplied, but are unnecessary.

(5) The general conception of the struggle for existence is that the slightest inferiority in structure or powers is sufficient to disqualify the individual for survival. From time to time, however, facts are brought forward tending to qualify this conception. An interesting example is given by Mr. W. E. Kellicott in *Science*, as the result of his study of an American species of toad. Out of four hundred and thirty-four individuals examined by him twenty-two showed injuries, such as crushed feet, broken femur, or broken scapula. In spite of these injuries, it did not appear that they had been very seriously handicapped in the struggle for life, for their average weight was 38½ grains, while that of the entire colony was 44¾ grains. In addition to this, sixteen showed abnormalities, some of which would appear to be serious disadvantages in the struggle for life. On the whole it is stated that the conditions of life were not rigorous for

this group of animals. Food was abundant, natural enemies not numerous, means of concealment and protection ready.

Still the fact remains that for animals the struggle for existence comes at crises of their existence. Thousands are carried off. For every species the struggle may become a stern reality at any time. "Quite apart from epidemics, it is probable that disease kills more wild animals than most people imagine. Even a small ailment must be fatal. . . . Among domestic animals it is frequent and visible enough. Even pigs get rheumatism or something like it."[8]

There is, therefore, usually and universally, a ceaseless struggle for food and place, and life, which ends in the survival of the fittest, and this, as in men of the same trade or profession, is very severe between members of the same species. Lions with keener sight and greater muscular development are able to combat lions of poorer sight and feebler form, and they survive, while the weaker ones go to the wall. The man with quick intellect and strong physical powers passes very rapidly the weak and the stupid in the race for life.[14] It is quite unnecessary to point out that the subtlety, variety, and complex character of the conditions of animal existence upon which natural selection seizes is amazing.

Protective colour and mimicry play a very important part in the struggle for life. The stripes of the tiger enable this animal to roam about and pass through forests of bamboo without being seen. Coral fish have most brilliantly coloured scales on their bodies, so that they may not be mistaken for living creatures but may look exactly like the coral on which they feed. Flat fish have a muddy or gravel-like colour upon the upper surfaces of their bodies, in order that they will not be observed lying on the mud.

That some flat fish, such as the turbot, are able not only to change their hues to conform to the colour of the gravel over which they happen to lie, but to copy on their upper surfaces the geometrical pattern of that background as well, has been observed by Mr. Francis Sumner in the United States Fisheries Laboratory at Woods Hole, Massachusetts, in 1911. Biologists have for many years believed that this alteration in colour of the skin was effected by the action of light upon its cells; but twenty-five years ago it was proved that the change

originated in the functions of the organs of vision. Blind fish are incapable of or, at least, do not change their colour adaptively. A distinct and detailed resemblance is noticed between the skin markings and the appearance of the gravel on which the fish lay, and by means of ingenious experiments it was shown that this was no mere coincidence, but that the fish had the power of controlling the colour pattern as well as the general colour tone of the body.

A number of different backgrounds was prepared, some simulating various types of natural sea bottom, and some imitating various unnatural geometrical patterns, such as stripes, screens, checker-boards, etc. After the fish had been placed in the tanks having one of these prepared floorings, it was found that it soon began to copy the pattern on its upper exposed surface. The time occupied in this alteration, ranged from a few seconds to several days.

This imitation of a geometrical figure is accomplished through the flat fish's eyes. The whole of the fish's visual field is not involved in the process; the imitation is not of all that the fish can see, but of the flooring immediately under or around it. When the fish was blinded it ceased to copy the background pattern, and became of an evenly distributed darker colour. Experimenting with vertical walls of different patterns and lines showed that no effect was produced upon the skin, and when the patterned flooring was placed over the fish no change was noticed.

It has long been known, too, that trout can at will change the colour of their bodies to match that of the bottom of the stream which they inhabit, and minnows also. All these instances are brought about by ocular means, and not, as is the case in certain insects, through the skin itself, or general nervous system.

In the insect world there are many beautiful examples of protective colouration. The leaf insects (Fig. 72), the butterflies, and moths show this. There is a South American butterfly whose upper wings are coloured blue and black, while its under surface mimics exactly the face of an owl. When it is pursued by a bird, all it has to do is to turn the under surface of its wings to its pursuer, which flies away on sight of the staring eyes of the supposititious owl. In the Zoölogical "Jahrbuch," 1910, Mr. Arnold Japha describes the "terrifying attitude"

of the Hawk-eyed moth. During the day this insect sits with folded wings on the willow, or other tree. The eye spot and the rose-red part of the wings are hidden, and the moth looks like a group of dried willow leaves. This is its protective attitude, by which it wishes to escape observation. But if disturbed it immediately assumes the "terrifying attitude." The eye spot and red are displayed, the thorax is arched, the abdomen curved up. This is accompanied by a protruding and retracting of the front of the body. The movement lasts some few seconds, or half a minute. This is thought to frighten the moth's enemies. The eye spot may suggest the eye of some much larger animal, while the energetic motion may give the impression that the enemy itself is about to be seized and devoured. But does the moth's "terrifying attitude" really frighten its enemies and allow it to escape? Standfuss tried some experiments with a view to settling this point. He gave specimens of the moth to nightingale, redbreast, black-cap, and other birds. Four out of five were obviously frightened when the moth assumed the "terrifying attitude," and left it alone after one trial.

Fig. 72

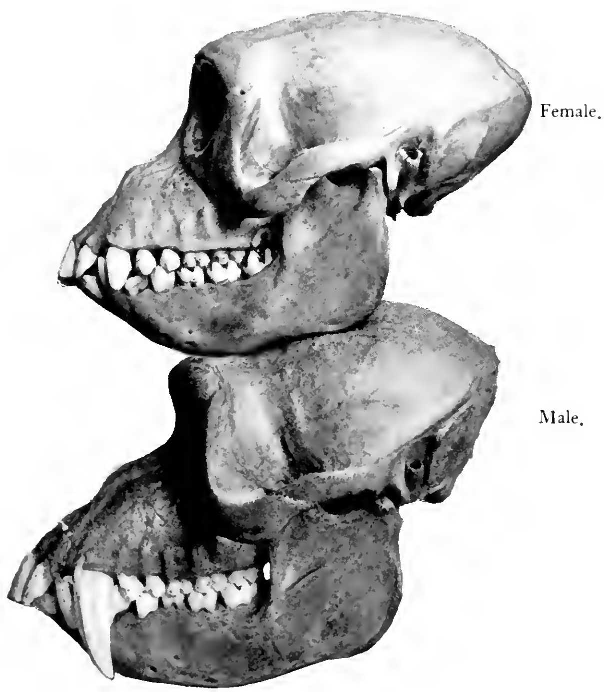
The *Phyllium* of Ceylon, an insect, shaped and coloured like a leaf. To illustrate protective mimicry in the *Orthoptera*. × $\frac{9}{10}$.

The "Kentish glory moth," a British species, passes its days on the bark of the birch, and by its mimicry of colour is thereby protected from the attack of birds, lizards, and other creatures. Nor is this confined entirely to the lower animals and insects, for the Bhils, of India, practise mimicry in order to escape their enemies.[12]

Sexual selection is a secondary cause of modification of species among animals. The struggle between males for the possession of females is seen, for instance, in a remarkable degree in the stags, and the deer, and the sea-lions. (See Chapter XVI.) Sexual selection explains the development of special features, which, transmitted in

increasing degree through a series of generations, probably bring about the survival of the fittest. Sexual selection has produced the varying colour of butterflies, the perfume of the musk-deer, the song of birds, and so on; and everything which gives an advantage or advantages to a plant or animal over its competitors in the struggle for existence. Dental examples may be given as follow: The male frugivorous monkeys have canines which are larger than those of the females

FIG. 73



Skulls of male and female Old World monkeys. $\times \frac{1}{2}$.

(Fig. 73). The male narwhal and the male dugong have tusks which in the female are quite insignificant and rudimentary. The musk-deer, as already noticed, possesses huge canines, while in the female musk-deer the canines are functionless. The male Sus Babirussa possesses huge tusks. In the female the upper canine is only three-quarters of an inch in length. The horse possesses canines, these teeth being rudimentary in the mare.

Now the necessity for food and the power to obtain it are probably the strongest stimulants to motion; and the animal which readily adapts itself to these, wins in the great struggle for life. The new functions which have to be discharged, involve changes in structure and form of the organs, because the organs exist for the work they have to do, not the work for the organs. The following curious and significant fact may be mentioned in this connexion. The antlers of some species of deer in a couple of months will grow so rapidly that they may weigh as much as seventy or eighty pounds. This rapid growth necessitates increased blood supply to the parts, and the added weight on the frontal bone requires greater power in the muscles and ligaments of the neck, and augmented strength in the bones to which the antlers are attached. More food, therefore, is required by the animal. This requires more active digestion, and, therefore, the digestive organs become structurally modified.

"Again, man, evolving from his quadrupedal and anthropoid predecessors, gradually acquired the erect position. This led to the flattening of the plantar region of the foot, and the accompanying growth and development of the *os calcis*. The vertebral column became curved in such a way as to best sustain the weight of the skull, and the heavy brain it contained, and a large number of muscles became rearranged and readjusted."[2]

Another example may be given. The ancestors of the whale-bone whales were land mammals, which had short fore and hind limbs, broad flat tails—like the beaver—many teeth, and well-developed olfactory organs. They were all omnivorous, lived in marshes, and fed on creatures which lived both on the land and in the sea. Conditions more and more adverse to life came on, and, under the influence of Natural Selection, the ancestors of the whales gradually became dolphin-like in their habits and structures, took to living in fresh water entirely; and then, when their natural enemies the ancient sea-lizards—whose fossil bones are still discovered here and there—had become extinct, found their way to the salt water of the seas, where they would be unmolested by their foes, and other land animals. As a result, the fore legs became flippers, the bones being homologous. Traces of hind legs can be found in some whales at the

present day. The tail became divided into two lobes, the head became fish-like, the seven cervical vertebræ became fused, the skin became hairless, and the teeth—which still appear in the rudimentary organs in whalebone whales—disappeared, and fringes of baleen were developed.

Among the herbivorous mammals the form of the teeth is adaptively modified for grinding instead of cutting.

In the *Carnivora*, the intellect is more highly developed, so that these creatures can stalk their prey, and, in their own fashion, think. Their bodies being reduced in size, their muscular strength gradually increased, their teeth and claws became adapted for readily attacking and seizing prey. And, last of all, in the *Primates*, the limbs, teeth, organs of digestion, are all slightly modified, and no organ of defence or attack developed. "The reason is that these animals took to an arboreal life, which induced but few variations of bodily structure, the most important being opposable thumbs and toes, for grasping. The need for alertness against their foes, however, sharpened their wits, and the necessity for mutual help and combination quickened their social instincts, so that the energy which in the herbivores and carnivores was stored in muscle and limb was diverted in the primates to the brain. Thus brain power conquered brute force, and skill overcame strength."[2]

Some of the *Primates* remained arboreal in their habits, though approaching bipedal movements in walking. Others developed a mode of progression on their hind limbs only, and were thus enabled to use their fore limbs for throwing, grasping, or handling things. This was the making of Man. The structural difference between Man and the anthropoid apes is very slight from a morphological point of view. More details of this will be given later on (see Chapter IX), but it lies in his larger and more complicated thinking apparatus—the brain, with its wonderful power of arranging, classifying, labelling, and numbering things, coupled with the faculty of enquiring into and discovering their origins, and the invention of articles of commerce, art, science, and war.

Proofs of Derivation of Species.[2]—The proofs supplied by living beings in support of the theory of their common descent are found

in (1) their *Embryology*, (2) their *Morphology*, (3) their *Classifications*, (4) their *Succession*, and (5) their *Distribution*.

(1) Embryology.—In the early development of animals it is impossible to determine whether a certain embryo is that of a bird, a lizard, a dog, or a human being, so closely do they outwardly resemble each other. In adult life, rudimentary structures frequently remain to point to this close affinity of living beings. Thus such dissimilar creatures as certain snakes and whales generally possess vestiges of a pelvis and hind limbs, all fœtal whales have tooth germs, and some non-flying insects have wings beneath their wing-cases.

(2) Morphology.—Certain likenesses of anatomical structure exist in widely different animals. There are seven cervical vertebræ in the long-necked giraffe and the short-necked pig; the ocular apparatus of the lamprey and the cat is controlled by six similarly arranged and similarly acting muscles.

(3) Classifications.—Plants are classified as flowering and flowerless; and animals, (*a*) those without body cavity, as the *moneron*, (*b*) those with body cavity, like the sea anemone, (*c*) those with digestive cavity separate and distinct from the body cavity, as the implacental mammals and Man.

(4) Succession.—The help afforded by the science and study of palæontology is very great in regard to fossil forms. For instance, the one-toed horse is shown to have been descended from the five-toed horse. Birds and reptiles have descended from the *Archæopteryx*, the pigs and hippopotamuses probably through the *Anoplotherium;* and the tapirs, horses, and rhinoceroses through the *Palæotherium*.

(5) Distribution.—All living things have their definite areas of range. Sloths are found in America, chamois in the Alps, hippopotamuses in Africa. The distribution of animals is due to the slow but ceaseless migration and transport of living things, rendered necessary by their rate of increase. Islands have an important part in the problem of geographical distribution, as in the marsupials, which are entirely found in Australia, a few being found in South America. And, finally, the agency of Man, by distributing new forms and destroying others, has done much in the same direction.

To sum up, Darwin's theory means that species have been modified

during a long course of descent. This has been effected chiefly through Natural Selection of numerous successive slight favourable variations, aided in an important manner by the inherited effects of the use and disuse of parts, and in an unimportant manner—that is, in relation to adaptive structures, whether past or present—by the direct action of external conditions and "by variations which seem to us, in our ignorance, to arise spontaneously."[3 4 5]

POST-DARWINIAN THEORIES

The Mutation Theory.—A post-Darwinian theorist arose in the Netherlands at the beginning of this century in the person of Hugo de Vries, who initiated what is known as the Mutation Theory, an elaborate study of certain species of plants which, under domesticated conditions, were able to produce numerous differences in size, shape, and colour of foliage, method of growth, etc. His work was called "Die Mutations Theorie."[13] He believes that new species have been produced *per saltum*, not by Natural Selection and Variation, which was the main principle of Darwinism. By artificial means, Burbank, of America, has been able to produce variations in fruits, vegetables, and flowers, but not new species.

The main argument against the Mutation Theory is that these so-called new species are unable to hold their own when in a feral condition, and that consequently they die out; whereas those produced by Natural Selection and Variations, such as those of the Protective Resemblance and Mimicry of butterflies and moths, do not.

The Mendelian Theory.—Darwinism has been replaced in the opinion of some modern Evolutionists by the recently revived theories of the Abbot Mendel, of Silesia, who flourished about A.D., 1850, the recrudescence of which practically synchronized with those of de Vries. The result of the Mendelian law appears to be a tendency to the perpetuation of certain pairs of characters without intermixture. Mendelian phenomena have been observed in peas, mice, rats, snails, poultry, rabbits, and some other plants and animals. While they furnish interesting materials for the study of the theory of heredity,

they have nothing whatever to do with the origin of species.[18] The results of Mendelian experiment are not constant. A law of heredity exists in the case of everything which possesses vital elements, identical in every particular, no matter whether it be of an animal or of a vegetable nature. This law defines, with mathematical accuracy, the parental qualities which will be handed down to progeny. Mendel the monk, observed its workings in his cloistered garden in Silesia when he interbred plants which had distinctive and peculiar characteristics. The strange features of the succeeding generations of certain "crossed" plants, and their repetition in definite and sharp exactness, induced him to propound a law which has since borne his name, and made him famous wherever scientists discuss the principles of heredity.

Mendelian law affirms that in cases where two strongly contrasting strains are crossed, one is likely to prove itself a "dominant," the other a "recessive."

Thus the resulting first generation of offspring would be all similar in appearance to the predominating strain, otherwise "dominants." Members of this generation beget progeny of which three-fourths follow the "dominant" pattern, and one-fourth show the characteristics of the weaker grandparent which was absolutely absent from the first immediate generation. In the third generation the character of the weaker member—the "recessive"—reappears in the offspring of those that had exhibited it in the second generation, and remain fixed, reproducing themselves indefinitely.

Similarly, the characteristics of 25 *per cent.* of the dominant strain in this generation become fixed. This leaves an unfixed 50 *per cent.* that would breed another generation with the characteristics partly fixed and partly unfixed, and in the same proportion as the previous generation. All the generations that followed from this unfixed division would be like the third generation in their characteristics and their proportions.

Results of Experiments.—In order to test the truth of these statements and verify this law, Dr. Schroeder, of the Department of Agriculture of the United States Government, experimented with rats which, being very fecund animals, offer abundant opportunities

for research. There are two plainly marked members of the rat family, the plain grey and the "hooded." The first is of a solid colour, the other being white with a black head. The colours are the distinctive points; and the identification of the two kinds of offspring easy to determine.

In the first generation, every member was solidly grey like the dominant strain of the parents. Two members of this family were interbred—not of necessity brothers and sisters—as other lines had been simultaneously started. In this case, the two grey rodents of the first generation produced part grey and part "hooded" offspring. The "hooded" rat which was suppressed in the first generation, appeared in 25 per cent. in the second. These "hooded" rats bred "hooded" rats in the following generations. Twenty-five *per cent.* of the greys bred all greys, a remaining proportion still having the unfixed characteristics, repeating the proportions of the second generation. This proved the correctness of Mendel's law of heredity.

If a black Minorca chicken is crossed with a white Leghorn, all members of the first generation will be white in colour. The second generation, however, will be 25 *per cent.* black as the original Minorca, in spite of the fact that both parents are white in colour. The white is the dominant colour; but the black was, so to speak, "released" in the second generation, and, thereafter, produced its like. In certain strains the crossing of the white and black results in a mottled white and black chicken, or in a bluebird. This happens when neither peculiarity is able to establish its supremacy, and where a compromise is possible.

If a four-toed and a five-toed chicken were crossed, the results failed to follow, because the supremacy of the one or the other was established, and would be complete. There are many exceptions to the rule, also, in individuals, for some mark their offspring strongly, while others fail entirely to do so. Thus a tailless game-cock will fail to produce one tailless bird when crossed with tailed hens, yet another similar game-cock will produce 50 *per cent.* of tailless progeny from the same hens.

Through the operation of this law a rose in the garden may develop traits of shape and features of colour which were not indicated by its

parents; horses and cattle revert to an early ancestry. Black-haired parents may, and do, beget blond or red-haired children. A man of unusual intellect is developed very often in a family the members of which are all stupid.

"This general law of heredity is intended as a guide for the farmer, the stock raiser, and the father of a family. From it he may forecast the future, and prevent the recurrence of the undesirable."[15]

Professor Alfred Russell Wallace[17] writes: "As playing any essential part in the scheme of organic development, the phenomena" above mentioned "seem to be of the very slightest importance. They arise out of what are essentially abnormalities, whether called varieties, 'mutations,' or 'sports.' These abnormalities are very rare in a state of Nature, as compared with the ever-present individual variability, ample in amount and affecting every part or organ, which furnishes the material both for Man's and for Nature's selection. The very fixity of these abnormalities, and the small number of the characters affected by them, as well as their rarity, all show them to be the refuse material of Nature's workshop, as proved by the fact that *none of them ever maintain themselves in a state of Nature.*"

It may be added that the Darwinian theory of evolution, and this theory only, can be, at present, applied to the evolution of the teeth, and that in all probability the Lamarckian, Mutationist, and Mendelian theories are predestined, in this sense, to fail, or in any degree to approach, the deductions of our Great Englishman.

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CHAPTER VI

THE IMPLANTATION AND REPLACEMENT OF TEETH

The Implantation of Teeth in Fishes, Reptiles, and Mammals.—The Replacement of Teeth in Fishes, Reptiles, and Mammals.—Vertical and Oblique Successions.—Absorptions: Physiological and Pathological.

SECOND only in importance to the size, shape, and position of the teeth, is their attachment by a fibrous membrane to bone or cartilage of the jaw, as the case demands; for no matter how well suited an organ may be for the requirements of its possessor in the comminution of food, in seizing and holding prey, and in fighting its natural enemies, unless a firm foundation is established and it is securely fixed in the soft or hard parts close by, it is a useless organ.

IMPLANTATION OF TEETH

In Fishes.—The great diversities in the shapes in the teeth of fishes, have already been described, and it is again this enormous group of animals that offers many varieties of implantations. The simplest of all is seen amongst the sharks and rays, where the teeth are fixed by ligaments to the margins of the jaws. On the marginal surfaces of the latter there are long grooves to give attachment to these ligaments which contain the teeth embedded in them. This is the simplest form, the teeth merely being surrounded by a thickened sheath of epithelial and dermal tissue, and their bases widened to serve as a method of support.

A more complicated variety occurs in what is called the "bone of attachment,"[5] in which a special building up of osseous material fastens the teeth to the oral bones. Thus, in the mouths of the eel and the wolf-fish, and in many other fishes, is found the "bone of attachment." In the case of the eel, the tooth is anchylosed to the

jaw, that is to say, the tissues of the tooth proper become blended with the tissues of the bone proper. This is the commonest method of attachment in the fishes, and is exemplified in the eel and the hake. Before complete anchylosis of the tooth has occurred during developmental periods, it is held to the jaw by a ligament either to the flat surface of the bone or to an eminence, or even to a depression in the osseous material.

A modification of this method is known as the "hinge" form, in which, as in the pike or the hake, one side of the tooth is not anchylosed, but is fixed to the "bone of attachment" by means of a hinge of elastic tissue fibres. The other side of the tooth is also not anchylosed to the "bone of attachment," but, being widened at the base, is placed in apposition to the "bone of attachment" on account of the virtue of the hinge on the other side of the tooth. The method is a most ingenious one for allowing some predatory fishes, like the hake and the pike, to grasp their living prey, and to prevent their food from slipping away from them; for in every instance, is the hinge fixed on the lingual side of the tooth, and the teeth, therefore, can bend inwards.

Amongst fishes also, the method of implantation known as gomphosis —which implies the means by which a nail is driven into a piece of wood—obtains. In this division there are (*i*) a simple fibrous gomphosis, (*ii*) a double gomphosis, and (*iii*) a bony gomphosis. With regard to the first, the rostral teeth of *Pristis*, the incisor-like teeth of *Sargus*, and the teeth of haddock are noticeable. It may be here noted that the position of the rostral teeth of the sawfish, imbedded in cylindrical cavities on the lateral edges of the rostrum by means of a fibrous tissue, and therefore outside the mouth entirely, is a specialized reversion to a condition which probably obtained in the ancestors of all fishes. The teeth of these creatures, in their most primitive condition, correspond exactly in structure with the small osseous enamel-capped granules of the skin, as in the sharks and rays, thus demonstrating that teeth were originally simple external organs, and also showing that teeth were homologous with the placoid scales of fishes.

As an example of bony gomphosis, the teeth of the mackerel—which are but slightly implanted—may be cited, where a small gutter

of bone intervenes between the teeth internally and the bone of the jaw externally.

The most complicated method of fixation known amongst the fishes will naturally be found in the mouths of those which have the hardest work to do from the dental point of view. Hence, it is not surprising that the file-fish, which has already been mentioned, should possess, in its incisor region a most excellent method for the implantation of its rodent-like teeth, for the purpose of efficiently chiselling through the shells of oysters and other molluscs. In this instance of double gomphosis the jaw and the tooth reciprocally receive, and are received by each other, a buttress of bone beneath the tooth spreading out in the form of a stud, to form a strong attachment.[3]

A final example may be given in the teeth of the *Diodon* or *Tetradon*, which are firmly fixed on the margin of the jaw, the structures of both passing insensibly into each other.

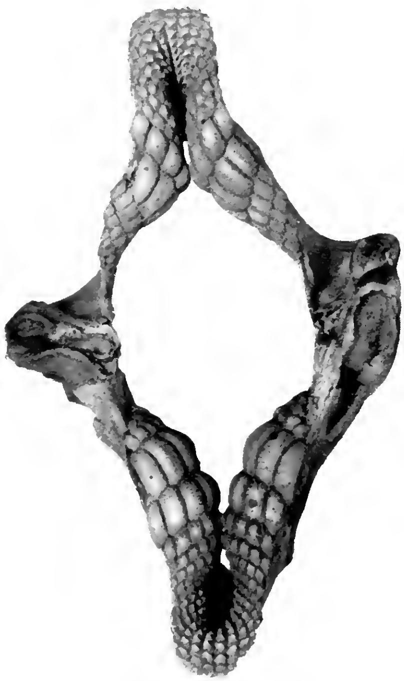
In Reptiles.—Amongst the reptiles, the method of attachment is by anchylosis. Simpler as the teeth are in shape and size, so is their attachment. When a reptile, like the *Varanus*, has its teeth anchylosed near the summit of the margin of the jaw, a *pleurodont* condition obtains; where, however, the teeth are fixed on the summit of the jaw, as in the iguana, an *acrodont* condition is spoken of. The crocodile, amongst the reptiles, differs probably more than any of the others in being a *thecodont* reptile. Here the teeth are apparently socketed, and not really anchylosed, as each tooth is surrounded by a sheathed condition of the soft tissues.

In Mammals.—Amongst mammals, sockets are generally found. They may be deep or shallow, wide or narrow, under varying circumstances, those occurring in the incisor region of the jaws of rodents being deepest for obvious reasons. Anchylosis is never found amongst the mammals, except on the authority of Sir William Flower, in the mandibular incisors of adult shrews, and extremely rarely, as a pathological condition, in the case of Man. Not more than ten cases of anchylosis in Man have been recorded,[2] and in one, which came under the notice of the author, it was associated with a disease of the bones of the face called *leontiasis osseum*.

THE REPLACEMENT OF TEETH

To complete this portion of the subject, a few words must now be said about the Succession of teeth, for it ought already to have been clear that some teeth are shed early, others taking their place; others may remain throughout the life of the animal.

Fig. 74

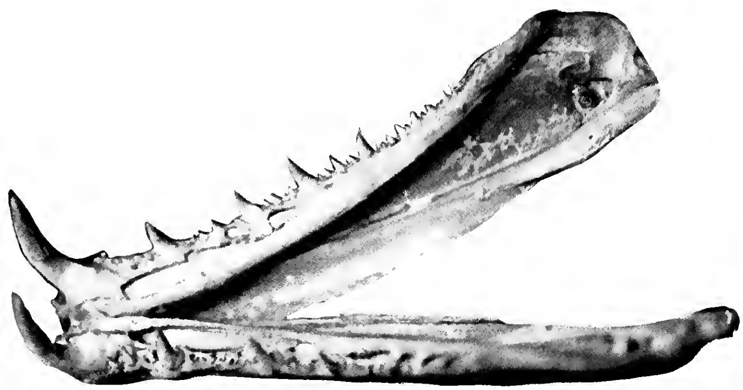


Jaws of the Port Jackson shark, *Heterodontis* (*Cestracion Philippi*). × $\frac{3}{4}$. Development proceeds from within outwards. The jaws are widely distended, and owing to their cartilaginous nature, have become somewhat distorted as a result of the drying of the specimen.

In Fishes.—In fishes, again, there exists a variety of methods of succession. For instance, in the sharks and rays there is a continuous replacement of teeth, that is to say, when one tooth has been shed, another tooth takes its place, and so on throughout the life of the animal. This is known as a Polyphyodont condition. The teeth of the sharks and rays, which are implanted in ligament, exhibit this continuous succession extremely well. It is probable that all fishes have a continuous succession of teeth, but the condition may be divided into three classes, in which there is (*i*) a Transverse continuous succession, as in the *Carcharias*, the word meaning transverse to the long axis of the mouth; (*ii*) a Longitudinal succession, as in the *Heterodontis* (*Cestracion Philippi*), where the teeth succeed one another from behind forward and move outward in an antero-posterior direction, passing in a line which corresponds to the long axis of the mouth; and (*iii*) in a Vertical direction, as in the file-fish, where an example is given of an isolated vertical continuous succession, and in the *Diodon*, which affords an illustration of a fused vertical continuous succession.

The mandible of the *Alepidosaurus ferox* exhibits (Fig. 75) a curious and interesting physiological provision, in case of accident or injury to the mouth. Toward the front of the jaw there are two strong, pointed teeth, longer than the rest, whose main function is evidently one of prehension of food. At the base of each tooth, enclosed in a horizontal cavity of reserve, lies a tooth similar in size and shape. If one or both of the functional prominent teeth happened to get knocked out, the successional tooth, lying in a horizontal plane, at once is ready to assume a vertical position, and actually takes the place of the lost functional tooth in an incredibly short space of time. According to the late Dr. Boulenger, of the Natural History Museum, this may occupy only a few minutes less than half an hour.

FIG. 75



Mandible of *Alepidosaurus ferox*. $\times \frac{2}{3}$.

It is known in this connexion, that if a poison fang of a viper is lost, another can replace it in a quarter of an hour.

In Reptiles.—In the reptiles, there is a continuous vertical succession, as exemplified, for instance by the crocodile and the lizard, also by the extinct gigantic creature known as the *Diplodocus*.

In Mammals.—Mammals exhibit what are known as (*i*) a Vertical succession, and (*ii*) an Oblique succession. Mammals may be either monophyodont or diphyodont, that is to say, they may have one set of teeth, or have two sets of teeth. Of the former, the Australian water rat and the English rat are good examples. Here the incisors

are continuously growing, they grow from "persistent" pulps; as their cutting surfaces get worn down by gnawing wood, etc., so more tissue is formed at the root, and the apical portion remains always widely patent.

It is probable also that the kangaroos and Australian mammals are, generally speaking, monophyodont with closed apical foramina to their teeth, but a diphyodont condition is usual in other mammals, the "milk teeth" lasting for a short period of the animal's life, and being succeeded by a permanent series. In all these cases the teeth are replaced more or less vertically.

The jaws of the elephant, in the order *Proboscidea*, however, show an oblique succession in the molar region. This animal throughout its lifetime has altogether only twenty-four molars, and when it is remembered that an elephant may live for three hundred and fifty years, it can be readily understood that it will not require the whole of the grinding surface of these molars for use at the same time. Therefore, what is known as an oblique succession of the teeth is produced, in which a small portion only of the morsal surface of the molars is brought into function at one and the same time. As this portion gets worn down the posterior portions of the teeth come into position.[5]

Fig. 76

Radiograph of right side of the mandible showing absorption of the roots of the second deciduous molar and its replacement by the second premolar. *Cf.* Fig. 77.

Fig. 77

Absorption of the roots of the second deciduous molar and no replacement by a premolar. The first permanent molar has been extracted.

Dental Absorption in Man.—In Man a limited vertical succession obtains, the roots of the deciduous teeth being absorbed, it is generally believed by means of a special tissue to which the name "absorbent

organ" has been applied. It is, here, a physiological process, assisted by the gradual development and eruption of the successional teeth. At times, however, there is no displacing tooth, yet the absorption of the roots proceeds as usual. The skiagram (Fig. 76) shows such a condition in the mouth of a girl of fourteen years. The second right mandibular molar of the deciduous series has almost completely lost its roots and there is no second premolar beneath. Fig. 77 placed by its side exhibits a normal condition.

It is not quite clear whether a special organ does exist. Soft tissue is often seen attached to the partially resorbed roots of deciduous molars, which, histologically, resembles granulation tissue, containing numerous myeloid cells which excavate the dentine by a kind of phagocytic action, and thereby produce the foveolæ of Howship.[2] Precisely the same occurs, from a microscopical point of view, in the pathological absorption of the permanent roots. Here, however, the process represents only one of the terminations of inflammation of the periodontal membrane, and may be localized to one tooth, or be more or less general throughout the whole dental series.[2]

Choquet,[1] in an important address, gives a chronological account of the theories which have been held regarding the absorption of the roots of the deciduous teeth, from the beginning of the Eighteenth Century, and describes the "mechanical" theory of Bunon, which was replaced by the "organic" theory of Burdet, who was the precursor of the theories of Delabarre and Sir John Tomes. He agrees, however, with Redier,[4] who advances the belief that this absorption is caused by a process of bone inflammation the effect of which is alternately to absorb old, and produce new bone, and he verifies this belief by personal experimentation. Redier's theory is considered by this author as no longer an hypothesis, but as an established fact.

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CHAPTER VII

DENTAL HOMOLOGIES

The Meaning of Homology.—Kinds of Homology.—Examples.—Meaning of Analogy.—Examples.—Difficulties of Homology.—Examples.

THE reader is now prepared, after discussing the nature, the functions, the number, position, shape, attachment, and succession of teeth generally, to understand their homologies. By this is meant that he will be enabled to determine approximately the denomination of any teeth in any given skull. Thus, it has already been mentioned that in the mouth of the giraffe, as in other ungulates, there are, in the front of the mandible, eight small teeth grouped closely together, the outermost of which, different in shape to the others, is used for tearing leaves from the twigs on which they grow. This fourth outer tooth has much the appearance of a modified incisor, but in reality it is a canine, although it bears no resemblance to such a tooth, and does not in the least conform to the definition already given of a canine. Reverting for a moment to that definition, it will be remembered that "a canine is that tooth behind the intermaxillary suture, if it is not too far behind;" and the lower canine is the tooth that, in occlusion, passes immediately in front of the upper one. In the case of the giraffe, however, there is no upper canine at all. This animal has, as usually obtains in many other herbivorous types, no maxillary front teeth, but bites on a thick, fibrous pad of gum in the front portion of the upper jaw. Is it possible, therefore, to determine whether this tooth is a canine or whether it is an incisor? One is helped by consideration of the homology of the teeth generally.

HOMOLOGY

Homology is the proof of the common origin of two organs.[1] It may be expressed, in other words, as "the morphological identity of representative parts in different animals."

Kinds.—There are four kinds of homology:

(1) Radial homology, exemplified in the starfish, in which all portions of the body bear an anatomical resemblance, and radiate from a common centre.

(2) Serial homology, as exemplified in the lobster or centipede, which creatures exhibit bilateral symmetry in the abdominal segments of their bodies.

(3) Lateral homology, which means structural identity of organs on both sides of the body, such as the antennæ of the butterfly; and

(4) Vertical homology, as in the front and hind limbs of the vertebrates generally, a term which means the similar structural identity existing between anterior and posterior appendages on the same side of the body.

Dental Homology.—Dental homology falls under the third division; it means the correspondence in relative structure, position, proportion, value, and development of the teeth, but not in shape or size or function.

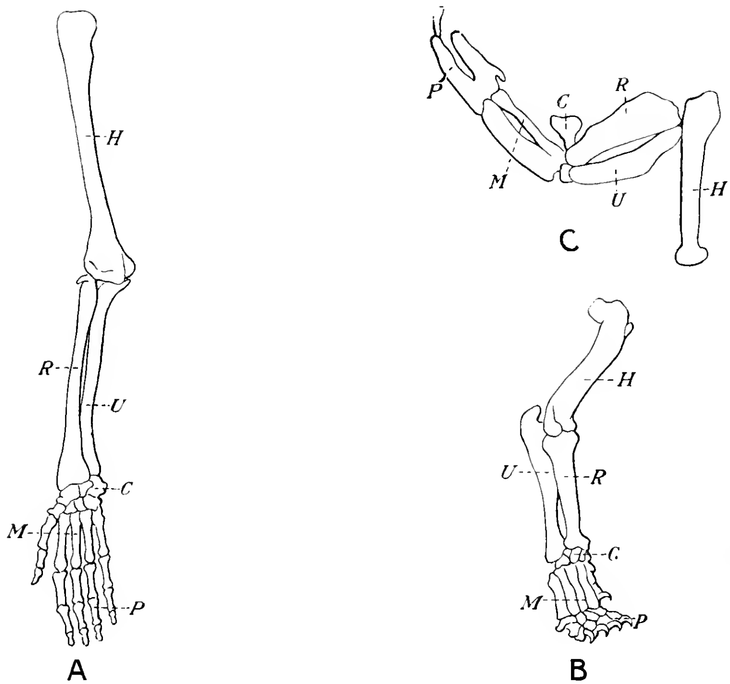
Teeth are said to be homologous with dermal spines, as, for instance, the placoid spines or the scales of the dog-fish.[4] Their structure and development is similar, if not identical. If a vertical section be made through the head of a young dog-fish, and it is examined microscopically, it is impossible to say, except by position, which is a dermal spine, and which is a young functional tooth. "The basis from which the matrix of a tooth of a shark and the antler of the deer grows, is homologically the same."[2] The homologies of the mammalian skeleton were first studied by Buffon, who was born in 1707, and died in 1788. The whole subject is an abstruse and yet very fascinating one. With regard to special dental homologies enormous difficulties exist.[1, 3] In order to get a clear conception of the terms "homology" and "analogy," examples may be given as illustrations.

Examples of Homology.—(1) Teeth and dermal spines, as already mentioned.

(2) Different organs, like the arm of a man, the foreleg of a dog, and the wing of a bird, which are morphologically similar. If, for instance, the bony framework of the arm, the foreleg, and the wing be examined, it will be found that there is in each case—in these different creatures, man, dog, and bird—a humerus, a radius, and ulna,

a series of carpal bones, and a series of metacarpal bones. They are identical from the point of view of anatomical structure, though, of course, it is obvious that they vary in size and in shape. They are not analogous, because they are used for different purposes.

FIG. 78



B *A*

Diagram to illustrate homology: *A*, the bones of the right arm of a man; *B*, of the right leg of a lion; *C*, of the right wing of a bird; *H*, the humerus; *R*, the radius; *U*, the ulna; *C*, the carpus; *M*, the metacarpus; *P*, the phalanges.

ANALOGY

Analogous organs are different organs which perform similar functions. Two illustrations may be given: First, the denticulate incisors in the lower jaw of the *Galeopithecus*, and the epithelial papillæ of the tongue of the cat; and secondly, the wing of a bird and the wing of an insect. It requires no effort of the imagination to conceive that the pectinate incisors of the *Galeopithecus* differ very remarkably, anatomically, from the lingual papillæ of the cat, as also the wing of

a bird differs morphologically from the wing of an insect. They are analogous organs, however, because they perform the same function, namely, that of combing the fur in the first instance, and flying, in the second instance.

Finally, examples of both homology and analogy may be cited. The leg of a man and the hind leg of a dog are both homologous and analogous, being structurally identical and performing the same functions. Also, the poison dorsal and opercular spines of the weaver fish.

As a rule, it is not a difficult matter to decide the homology of a certain tooth. In connection with the fourth outermost tooth of the giraffe, sheep, ox, etc., however, the reader knows that in the typical mammalian placental dentition there are three incisors only, and the fourth tooth, which does not supply an answer to the definition already given of the lower canine, must be this tooth on account of its homology in other animals.

The classical definition of the upper canine holds good with regard to the jaws of dog and man and many animals. A problem, however, occurs in the jaws of the mole with regard to its teeth, for the upper canine-like tooth is in front of or within the intermaxillary suture, while the lower canine-like tooth occludes behind the upper one. Hence, while the upper tooth may be analogous with the canine in mammals, on account of its value as a seizing tooth, its anomalous position makes it a very large fourth incisor. Regarding the mandibular canine-like tooth, the fourth incisiform tooth must be regarded, if this definition is correct, as a true canine, although the first premolar, larger than the others, is functionally the true canine. The dental formula of the mole is,[4] as has already been pointed out, $I\ \frac{3}{3}\ C\ \frac{1}{1}\ Pm\ \frac{4}{4}\ M\ \frac{3}{3} \times 2 = 44$.

In some other members of the *Insectivora*, the premolars are caniniform in shape. The first lower premolar and the upper third incisor are like canines in appearance; and again other groups have no tooth specially pointed or specially functional. It is probable that no mandibular incisor becomes canine-like to oppose an upper canine.

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CHAPTER VIII

THE EVOLUTION OF THE MAMMALIAN CROWNS

The Production of the Complexities of Patterns of the Mammalian Crowns.—The Concrescence Theory; Evidence in Favour.—Examples.—The Tritubercular Theory.—The Work of Cope, Osborn, and Wortman.

THE PRODUCTION OF THE PATTERNS OF MAMMALIAN CROWNS

It is not necessary, after what has already been said, to emphasize the fact that the back teeth of most mammals present a very complicated pattern from their coronal point of view. How is it that they present these complex patterns? Why, for instance, is it that the molars of the elephant—of which two species only remain, the Indian and the African—are not the same? In other words, "How has it come about that the molars of mammalian teeth present a great number of cusps?" The problem has puzzled the minds of many biologists.

At the present time, it may be said, briefly, that three schools of thought are divided as to the origin of the cusps of the mammalian teeth. These may be known, first, as the Fusionists, secondly, the Tritubercultists, and thirdly, the Multituberculists.[6] The former hold that through the shortening of the jaws the haplodont teeth of the primitive type become fused, and ultimately molariform in shape. This is the theory of Röse,[9] Virchow,[14] and Kükenthal,[4] its modern exponent being Marett Tims.[7] The latter hold that simple haplodont teeth have cusps developed upon them. It is necessary to consider the various ideas of the two first-named schools of thought.

THE CONCRESCENCE THEORY

If the theory of the fusion of haplodont teeth was correct, one would expect to find that the molars or back teeth of Mesozoic animals would be of a simple type and pattern, and those of an earlier period in the

history of the world still again simpler; but this is not the case. The earliest known mammal is probably the *Microlestes*, the progenitor of the rat kangaroo of Australia. The molar teeth here are somewhat similar to the molar calcified teeth of the *Ornithorhynchus*, and show no signs whatever of a simpler formation. Still, the reader is inclined to ask, "Why do the supernumerary and supplementary teeth of the *Primates* nearly always approximate the shape of a cone?"

Fig. 79

Radiograph of two supernumerary incisors, above and below an unerupted maxillary first right incisor.

Is it unreasonable to suppose that these ill-formed, stunted, peg-shaped teeth are really an attempted expression of Nature, of certain atavistic proclivities on the part of Man, and that in themselves they may be considered to be evidences of his reptilian descent? (Fig. 79). Is there any truth in Lepkowski's[5] observation that whereas front teeth have usually one bundle of blood vessels, back teeth possess two or more bundles? Let the student examine the developing molars of the elephant, and many of the larger animals, and he will clearly see an apparent fusion of simple cone-shaped bodies which go to form the teeth. The molar teeth of the mastodon or the mammoth exhibit in their youngest portions a conglomeration of a few cones. (See also Fig. 315.)

As a latter-day teacher of this theory as to the complex pattern of the mammalian crowns, one must refer to the works of Marett Tims.[7] He has shown, first, that in the fishes there is, in certain cases—as in the mud-fish (*Ceratodus*)—a fusion of individual cusps; secondly, amongst the reptiles there are evidences of a concrescence in the development of the teeth of *Sphenodon*. This concrescence theory implies, therefore, a fusion of reptilian cones, which give rise to the various cusps of the mammalian molars. Marett Tims adopts this theory as far as it relates to the anterior position of teeth of the same dentition in the true molar region only. He has never seen fusion of mammalian enamel organs. He has noticed a striking numerical relationship between the cusps of mammalian teeth and the number of individual teeth.

Regarding the premolars, the base of the reptilian cone is surrounded by a cingulum, which has already been mentioned. In process of evolution, the external part of the cingulum disappears, the ends of the internal cingulum give rise to small anterior and posterior cusps. In this way, what is called a triconodont tooth is formed. An examination of the jaws of the hyæna and the cat shows this beautifully, the upper third premolar in each case presenting obviously a three-cusped tooth. These cusps increase in size, and the premolars are very pronounced, both in the cat and in the hyæna. The fourth upper premolar is a very large tooth, namely, the "carnassial" tooth, as already mentioned. Marett Tims believes that the origin of these anterior and posterior cusps, which are merely an elevation of the ends of the internal cingula, may be due to mechanical agencies. Regarding the molars, he considers that the complexity of the pattern of the crowns is chiefly due to longitudinal fusion of primitive haplodont cones.

The cingulum of the dog shows an elevation into cusps in the incisors, premolars, and molars.

THE TRITUBERCULAR THEORY*

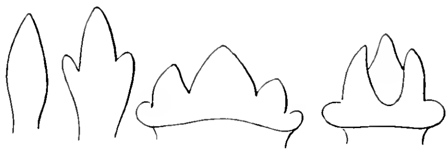
This theory holds that haplodont teeth have cusps developed upon them. From America came its origin. Cope[3] and Osborn[9] are the great exponents of it. They found, in a fossil jaw of a small extinct mammal, certain primitive haplodont cone-shaped teeth of a reptilian pattern. This was the *Dromotherium* [δρομαῖος = running, θήρ = wild beast ("the running animal")], and the tooth consisted of one main cone with minute lateral cusps upon it, the root being grooved. Here was evidence, to their mind, of the first stage of this Tritubercular theory, namely, one main cone, with minute lateral cusps upon it. In order to distinguish this principal cone from others, it was called the protocone (πρῶτος = first).

The second stage of the theory depended upon the development upon this primitive cone, of anterior and posterior cusps. This con-

* This term is inaccurate, as pointed out by Beddard ("Mammalia," Cambridge Natural History, 1902, vol. x), "for the holders of this view do not derive the mammalian molar from a trituberculate condition, but in the first place from a simple cone, such as that of a crocodile."

stituted what is called the Triconodont stage, and is exemplified in the jaw of the ancient mesozoic mammal, the *Amphilestes* [λῃςε-λῃστὴς ("the robber")]. Here was a crown elongated in an anterior and posterior direction, consisting of one central cusp and two lateral cones, the root being bifurcated. The cone in front of the main cone or cusp (protocone), was called the paracone, the posterior cone was called the metacone. Therefore, from before backward, the three cones were known as para-, proto-, and meta- ("before," "First or principal," and "behind"). Examples of these triconodont teeth may be seen in the cheek teeth of the leopard-seal at the present day.

FIG. 80



A *B* *C* *D*

The stages of trituberculism. (After Osborn.) *A*, hypothetical pattern of haplodont type, unknown as yet in primitive mammals. *B*, protodont type, the main cusp (*protocone*), having in front the *paracone* and behind the *metacone*, exemplified in the *Dromotherium*. *C*, triconodont type, the three cusps are more equal in size, exemplified in *Phascolotherium*, and the leopard seal. *D*, tritubercular type, the crown being triangular, exemplified in *Spalacotherium*.

The third stage, or the Tritubercular stage, is exemplified in the molar teeth of the *Spalacotherium* (σπάλαξ = a mole). This Triconodont tooth was not elongated in an anteroposterior direction, but modified into a triangular form, that is to say, the anterior and posterior cones, instead of being in a straight line with the protocone, had been placed to the side, and the three cusps or cones were thus arranged in a triangular form. The molar teeth of the mammals of the present day exhibit this Tritubercular condition. Osborn[8] believed that, in the evolution of countless ages, the lateral dental cones of creatures like the lemurs, rotated inward in the mandible, outward in the maxilla. In each case the protocone formed the apex of the triangle. In the upper jaw it is on the lingual side; and in the lower jaw it is on the labial side.

This is the theory. What support is there for it? Only the existence of the lower molar of this *Spalacotherium*, which was a marsupial,

whose remains are extremely old, and whose jaw from which these deductions were made, was perhaps only one and one-half inches in length. The Tritubercular theory is probably correct as to the evolution of the *three main cusps;* but the chief objection lies in the absence of embryological details, and the entire want of evidence to show that rotation of cusps takes place.

Investigating the evolution of the molars of Man, these two American observers name the various cusps appearing on the crowns in conformity with their ideas regarding the Tritubercular theory. Two illustrations may be given as to the results of their work. Considering the first maxillary molar on the right side, which is a four-cusped tooth, fairly quadrilateral in shape in a typical specimen, the anterior internal cusp is the most prominent and marked. This is the *protocone*, and it corresponds to the apex of the primitive triangle or "trigon" of Osborn. It is connected by means of a ridge with the posterior external cusp which corresponds to the *metacone* of the Trituberculists. The anterior external cusp is the *paracone*, and in the three cusps there is the primitive triangular form, the *protocone*, as has already been said, being the apex and looking inward toward the palate, the *paracone* forming the anterior angle, and the *metacone* forming the posterior angle. But in addition to these three, a fourth cusp is observable, occupying a posterior internal position. This is termed, by Cope and Osborn, the *hypocone*, which is not represented in the original triangle, but means the "Cone beyond" the original triangle.

Passing on to the first mandibular molar on the right side, it is seen, in a well-formed tooth, that five cusps are represented on the occlusal surface of the crown, two anteriorly, two posteriorly, and one intermediate between the two posterior cusps. These may be termed respectively, the antero-external, the antero-internal, the postero-external, the postero-internal, and the postero-median, or intermediate cusp. The application of the Tritubercular theory to this tooth is not so easily accomplished as in the upper molar, but acting on the assumption of the apex of the triangle occupying the labial side in the lower jaw, the protocone, therefore, corresponds to the antero-external cusp. Be it noted, however, that in the mandible the suffix "id" is applied to the word cone to distinguish it from the upper jaw, so one

speaks of the antero-external cusp as the *protoconid*. The *paraconid*, apparently, cannot be accounted for in this first right lower molar tooth. The *metaconid*, however, remains, and can be identified with the antero-internal cusp, while the *hypoconid* is represented by the postero-external cusp. The postero-internal cusp is known as the *entoconid*, and the postero-median is known as the *hypoconulid*.

The probable order of the appearances of the cusps of the molars from a histological point of view is as follow:

MAXILLA

Primates	*Marsupials*	*Ungulates*
1st. Paracone	1st. Paracone	1st. Paracone
2d. Protocone	2d. Protocone	2d. Metacone
3d. Metacone	3d. Metacone	3d. Protocone
4th. Hypocone	4th. Hypocone	4th. Hypocone

MANDIBLE

1st. Protoconid	1st. Protoconid	1st. Protoconid
2d. Metaconid	2d. Paraconid	2d. Metaconid
3d. Hypoconid	3d. Hypoconid	3d. Hypoconid
4th. Entoconid	4th. Entoconid	4th. Entoconid
5th. Hypoconulid	5th. Metaconid	

The foregoing is a fair statement of the observations of Cope and Osborn. The reader is referred to their works and those of other observers for fuller accounts.

In attempting to apply the cone theory to the incisors, the canines, and the premolars, one may point out that the *incisor* may have been derived from a cone which had a flattened base, flattened in an antero-posterior direction to make the incisive edge. In the *canine*, the base is transformed into a trihedral cone-like prism. In the *premolars*, at first sight there is a probable fusion of two cones with rounded bases.[12] Examination of a typical first maxillary premolar shows apparently a duality of cones, of which the larger is on the outer (buccal) side. The union of the two is incomplete as in the second premolar. It is difficult, however, to consider this as an example of fusion of two cones, on account of their relative positions. They are placed laterally, and never occur in the antero-posterior diameter of the tooth. This lateral position would presuppose that (*i*) there is fusion by two cones of dissimilar dentitions of which the buccal would represent the older,

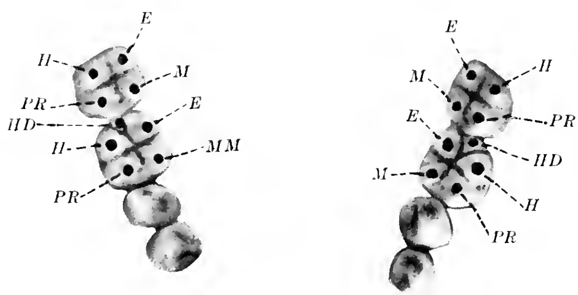
and the lingual the younger of the two, *viz.*, the permanent and the post-permanent types, and (*ii*) that both dentitions were equally evolved. While there is no obvious dissimilarity in size, it is conceivable that an undue elevation of the internal portion of the cingulum of the protocone, represented by the outer cusp, probably explains the prominence of the lingual cusp of the tooth. The other anterior teeth—incisors and canines—often exhibit a small cusp on the lingual surface which is evidently the elevated cingulum of the typical tooth.

This theory of Trituberculism, as propounded by Cope and Osborn, has been controverted by many people.

FIG. 81

The crown of the first right and left maxillary molars, showing the homologies of their cusps. × 1/1. *PT*, protocone; *PA*, paracone; *M*, metacone; *H*, hypocone.

FIG. 82



The crowns of the first and second right and left mandibular molars, showing the homologies of their cusps. × 1/1. *PR*, protoconid; *H*, hypoconid; *HD*, hypoconulid; *E*, entoconid; *M*, metaconid.

Objections to the Tritubercular Theory.—A recent writer—Wortman[16] —who has studied the question very considerably, advances an idea which seems more plausible than the above. The *Carnivora* today are derived from three ancient sub-orders: (1) The *Creodonta*; (2) the *Carnivora* or the *Carnassedenta*; (3) the *Pinnipedia*. In the

Creodonta, the carnassial tooth may be absent or present; when present, it is not always the fourth upper premolar and first lower molar. There is no living representative of the *Creodonta* today, but their fossil bones have been discovered in the Eocene strata in Wyoming and Utah, and also in New Mexico. Among the Creodonta were the animals *Dissacus* and the *Mesonix*. In these, the lower molars have lost the internal cusp of the triangle, that is, the protocone. The pattern of the teeth thus assumes a simple premolar-like shape. This is not a degenerative change. But the upper teeth are of great importance. In *Dissacus*, the first and second premolars have simple crowns and one small posterior heel. The third premolar shows a transitional stage, a second heel developing on the lingual side of the principal cusp. The fourth premolar is the same, but still more advanced, namely, the tooth consists of a principal cusp, a heel or posterior external cusp, a lingual cusp, and a small posterior intermediate cusp. In the first upper molar, the tooth crown is nearly triangular, because of the increase of the size of the postero-external and the longitudinal cusps, but the antero-external cusp is still the larger. The second molar shows a state of development intermediate between the fourth premolar and the first molar. In *Mesonix*, the first and second premolars, little change from the simple type was noticed; the third premolar had a postero-external cusp or heel, and no internal cusp, but the heel was increased in size till it and the principal cusp were equal. In the fourth molar the postero-external cusp has increased in size till both are equal, and the internal cusp has increased in size, making the tooth look like a molar. The first and second molars are very similar.

Now take a single cone-shaped premolar and follow it through many series of jaws of ancient mammals, and the result of one's study shows that certain new cusps come to be added in a different way. Thus, first, a cusp is added to the posterior border as a basal heel; secondly, an internal cusp arises from the cingulum and becomes the main internal cusp of the tritubercular crown. The exact order of appearance is, however, not constant. But Scott[11] has shown that the tritubercular crown of every complicated premolar thus far known among placental mammals has originated by the addition of these two cusps in these

situations, having in every case the primitive cusp at the anterior-external angle, and, therefore, he calls these the protocone, the tricone, and the dentary cone on the lingual side.

Now, Wortman believes, and his theory seems more likely to be correct, that as there is so much similarity in the fourth premolar and the molars of *Dissacus*, there is no doubt that the postero-external and internal cusps have been added to the protocone and the original molars in exactly the same manner and precisely the same order as they have been in the premolars as seen in *Mesonix*, and, therefore, Osborn's "rotation" theory is wrong.

To conclude, a summary of what has already been given may be added. The Fusionists believe in the fusion of several simple cones, as in the reptiles; the Trituberculists—of whom Osborn believes in rotation of cusps and Wortman no rotation, but mere addition of cusps—find that in fossil mammals the simple cone had cusps added to it.

As has already been stated, there is a constant succession of teeth in fishes and reptiles; there can be little doubt that the milk and permanent teeth of mammals represent a part, at least, of the successive series of reptilian teeth. Much discussion has taken place as to which of the two dentitions is the primary in mammals. The deciduous dentition is the first in mammals, generally; but in marsupials it appears to be absent. The truth probably is that it is rudimentary in *Marsupialia*. Some believe that in Man there may be a pre-milk and post-permanent dentition. Vertical sections of human jaws show occasionally a budding out from the tooth band on the labial side and a budding out from the tooth band on the lingual side, in addition to the presence of milk and permanent tooth germs. Some believe that there are evidences, therefore, that there are four dentitions in such a section; that on the labial side being the pre-milk, that on the lingual side the post-permanent enamel germs. Sufficient data, however, are not forthcoming on the subject, and until it can be proved that these accessory buddings from the tooth band are true enamel organs, and are about to produce enamel, it is impossible to state clearly that these evidences of extra dentitions are present in Man. If it were so, of course, it would represent a reversion to a

reptilian dentition, and taken in conjunction with the characters by supernumerary and supplemental teeth, tend to prove a mammalian descent from reptilian progenitors.

In addition, the interested reader should consult the writings of Adloff,[1] Ameghino,[2] Ryder,[10] and Topinard.[13]

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CHAPTER IX

THE TEETH OF THE PRIMATES

Introductory.—The Teeth of the Lemurs and the Anthropoid Apes.—Prehistoric Man.—Rules for Descriptions of Mammalian Dentitions.—The Dental Index.—The Facial Angle.—The Gnathic Index.

CLASS I. MAMMALIA

Sub-class II. Eutheria

The process of evolution has reached its highest degree of development in the class of vertebrates called *Mammalia*, and in the order *Primates* (*Primus* = first, *phonetically* Pri-ma-tes).

The first ordinal group of Eutherian Mammals designated *Primates* originally by Linnæus, is, as its name signifies, the first of all the artificial subdivisions of warm-blooded animals which suckle their young, whence the name *mammalia* is derived. By some authorities[1] it is placed last on the list. For present purposes, the classifications of Flower and Lydekker[5] and Beddard[1] may be adopted. A survey of these sections and divisions thus shows, at a glance, the position of Man with regard to the other members of the same group, and the other orders of *Mammalia*.

The members of this order may be defined as Mammals which are completely hairy, and generally arboreal, possessing on all four limbs five digits, usually provided with flat nails, the terminal phalanges expanded and flattened at the terminations. Plantigrade, the fore feet, as a rule, are grasping organs, the hind feet being used for both grasping and walking. The mammæ are thoracic (except in the *Aye-aye*), and sometimes are placed in the axillæ. The orbits and the temporal fossæ are partly separated by an osseous ridge. Clavicles are universally found. The lunar and scaphoid bones are separate. The femur has two trochanters. The stomach is a simple sac, except in the sacred apes of Asia. A large cæcum is invariably present.

The main reasons why Man is included in the Monkeys and small family of Lemurs, as apart from other Mammals, lie in certain anatomical features which are common to all. Thus, in all, the hand is a grasping organ, furnished, except in some few instances, with five fingers. The thumb is, in the majority of cases, opposable, and in the five-toed hind foot, the thumb (great toe) is similarly opposable, except in man. A second distinctive feature is that the bony orbits of the eyes are surrounded by an unbroken osseous rim. Thirdly, certain general dental characteristics are found, except in the marmoset monkeys, and consist of the broadening and flattening of the crowns of the molars, which are surmounted by cusps or ridges, form three pairs on each jaw, are always more complex in pattern and larger in size than the premolars, and are admirably adapted for the mastication of fruits, leaves, and vegetable substances.

The Order consists of:

Sub-order I. *Anthropoidea—Anthropoid apes.*

Family I. *Hominidæ*, comprising one genus *Homo*, and one species *Homo sapiens*—MAN.
Family II. *Simiidæ*—Man-like apes.
Family III. *Cercopithecidæ*—Old-world monkeys.
Family IV. *Cebidæ*—American monkeys.
Family V. *Hapalidæ*—Marmosets.

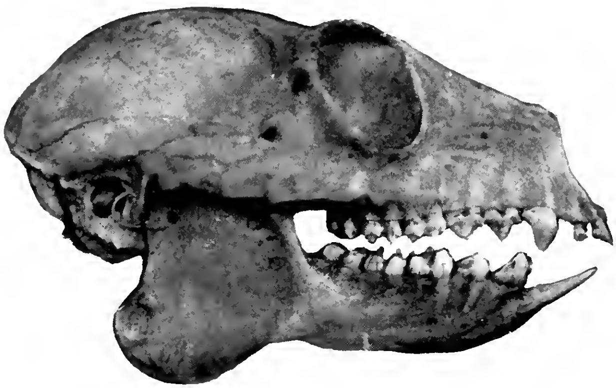
Sub-order II. *Lemuroidea*—Lemurs.

TEETH OF LEMURS AND ANTHROPOID APES

Of these, the Lemurs (*Lemur*—a ghost) are of the lowest type. Natives of Madagascar, and of nocturnal habits, they may be also found in Africa and the southern parts of Asia, but in the first-named locality they attain their maximum development. They differ from monkeys in that they have longer limbs, smaller fox-like skulls, and different dentitions. A distinctive character of this group is the fact that the second toe of the hind foot always terminates in an elongated curved claw or talon.

The dentition of typical lemurs consists of two pairs of maxillary incisors, separated from one another by a considerable gap in the middle line, and four slender mandibular procumbent (horizontally placed) incisors. The upper canines are large. The lower ones small, like incisors—and there is some doubt about their homologies. Hence, some authorities[5] call these teeth third incisors.

FIG. 83



Skull of a typical lemur. $\times \frac{4}{5}$. The mandibular third premolar performs the functions of a canine.

Their dental formula is: I $\frac{2}{2}$ C $\frac{1}{1}$ Pm $\frac{3}{3}$ M $\frac{3}{3}$ x 2 = 36.

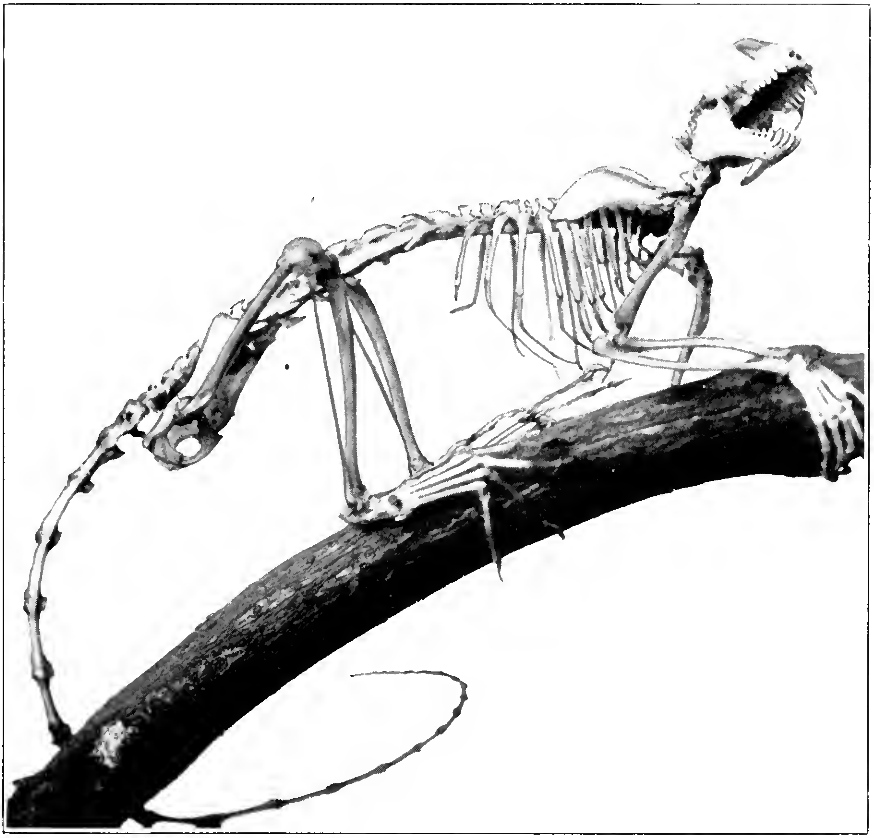
The most aberrant member of the group is the Aye-aye (*Cheiromys:* χεὶρ = hand; μῦς = mouse), an arboreal animal which mainly eats caterpillars which it pulls out of the holes of trees which they have bored. Its incisors are rodent-like in appearance and use, for they are employed in gnawing through the stems of the sugar cane.

Its formula is: I $\frac{1}{1}$ C $\frac{0}{0}$ Pm $\frac{1}{0}$ M $\frac{3}{3}$ x 2 = 18.

The American monkeys (*Platyrrhini:* πλατὺς = broad; ῥὶς = nose) include ten genera, such as the Howlers, the Capuchins, the Spider Monkeys, the Squirrel Monkeys, etc., and differ so very markedly from the Old World forms, that it is quite possible they may trace their origin from an altogether independent source, and if the anatomy of their teeth is to be depended upon for information upon this point, it would seem as if their origin was lower and less specialized than that of the latter. Thus, they possess three pairs of premolar

teeth in each jaw, their formula being: I $\frac{2}{2}$ C $\frac{1}{1}$ Pm $\frac{3}{3}$ M $\frac{3}{3}$ x 2 = 36. The nostrils are widely separated, and most have tails, which, when long, are frequently prehensile. The thumb is non-opposable. They inhabit the tropical districts of Brazil. The marmosets are distinguished dentally in that they have only two pairs of molar teeth in each jaw.

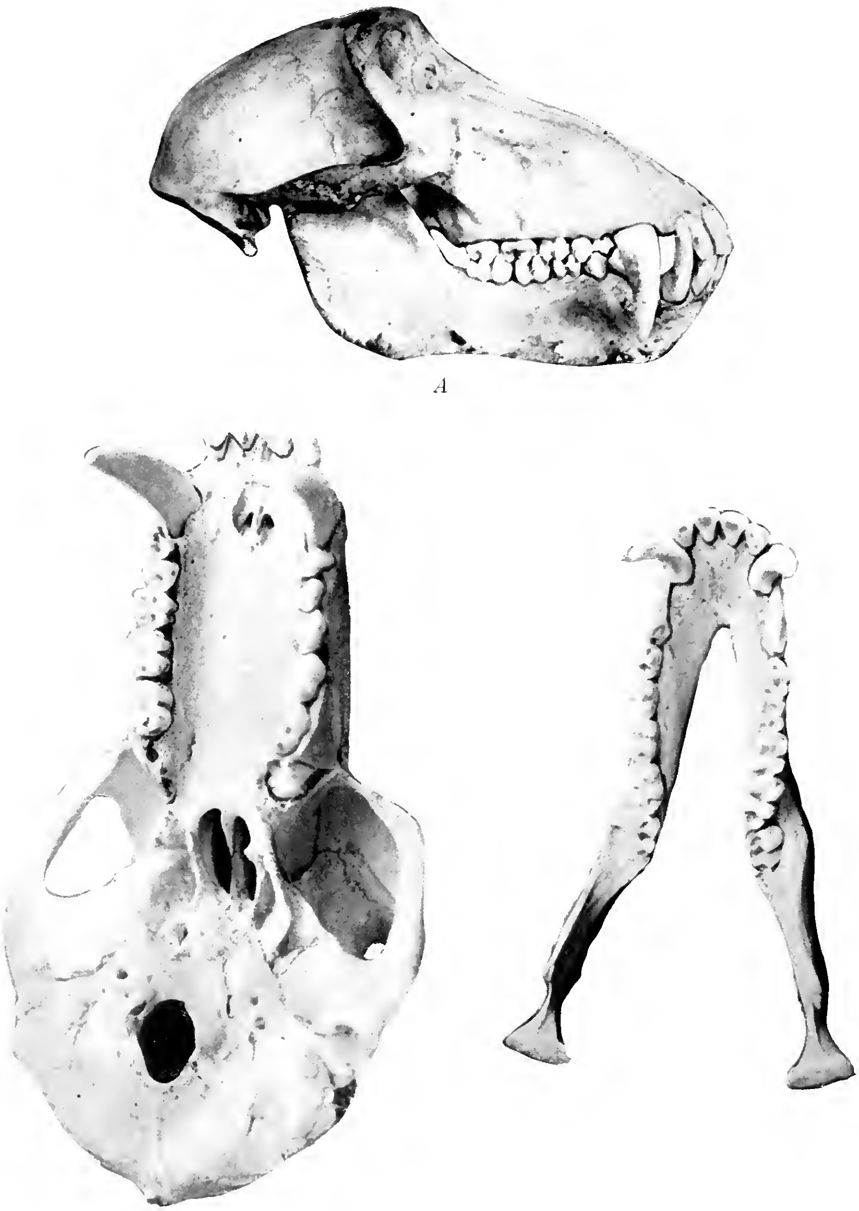
FIG. 84



Skeleton of a New World monkey (*Midas*). × ½. *Cf.* Figs. 92 and 93. The marmosets, of which this is a photograph, possess only four pairs of molars in each jaw.

The Old World monkeys (*Catarrhini:* *κατὰ* = down or narrow, *ῥὶς* = nose) include the Orang-outang of Africa, the Gorilla of Africa, the Gibbon of Borneo, and the Chimpanzee of West and Central Africa. Some naturalists place amongst the Old World apes the

Fig. 85



A

B C

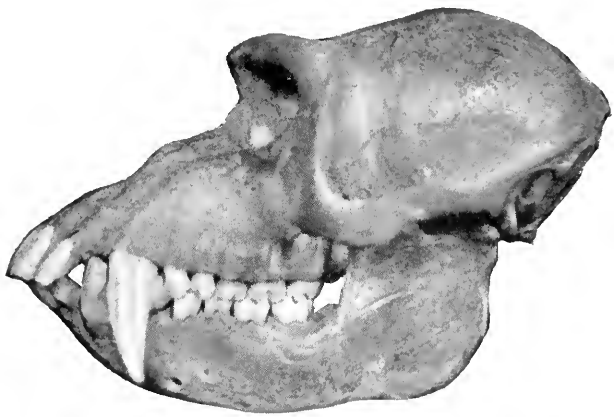
Skull of a baboon (*Cynocephalus*, or *Papio*). $\times \frac{1}{2}$. The crown of the mandibular first premolar inclines greatly backwards. *A*, side view; *B*, palate; *C*, mandible. In the latter supernumerary molars are present.

Baboon and the Mandril,[3] of Arabia and Africa. These differ from the former by their mode of progression "on all fours," by having longer legs than arms, and by the first incisor being greater than the second incisor.

In all, the dental formula is the same as in Man: I $\frac{2}{2}$ C $\frac{1}{1}$ Pm $\frac{2}{2}$ M $\frac{3}{3}$ x2 = 32.

According to Professor Lydekker,[7] "These dental characters afford very important evidence of the close kinship of the man-like apes to Man himself, and undoubtedly outweigh the difference in the form

FIG. 86



Skull of an Old World male monkey, the macague (*Macacus rhesus*). $\times \frac{2}{3}$.

of the whole dental series now to be noticed, which is largely due to adaptation. In both the upper and lower jaws of Man the teeth are arranged in a regular horse-shoe series, with scarcely any interruption to the continuity, by the tusks which are but little taller than the other members of the series. On the other hand, in the adults (and especially the males of the larger species) of the man-like apes, the cheek teeth are arranged in a nearly straight line, and form a more or less regulated junction with the line of the incisors; the large canines or tusks, occupying the angle between the two series, and thus forming a marked break in continuity. In these respects the man-like apes resemble their inferior kindred. If, however, a young individual of the larger man-like apes, and especially the chimpanzee, be examined, it will be found that the teeth, owing partly to the imperfect protru-

sion of the tusks, form a less interrupted and more regularly curved series. Indeed, with the exception that the whole jaw is longer and narrower, and the partially protruded tusks are proportionately larger, the character of such specimens make a marked approximation to the human type, and the jaw of a chimpanzee at this stage may be regarded as almost intermediate in structure between that of Man and that of an adult male gorilla. Moreover, in this juvenile state, the long union of the two branches of the lower jaw partakes of the short and rounded form characterizing that of Man; whereas, in the adult it becomes longer and more deeply channelled, like that of the lower monkeys. In many respects the teeth and jaws of the gibbons, or smallest representatives of the present group, conform to the intermediate type."

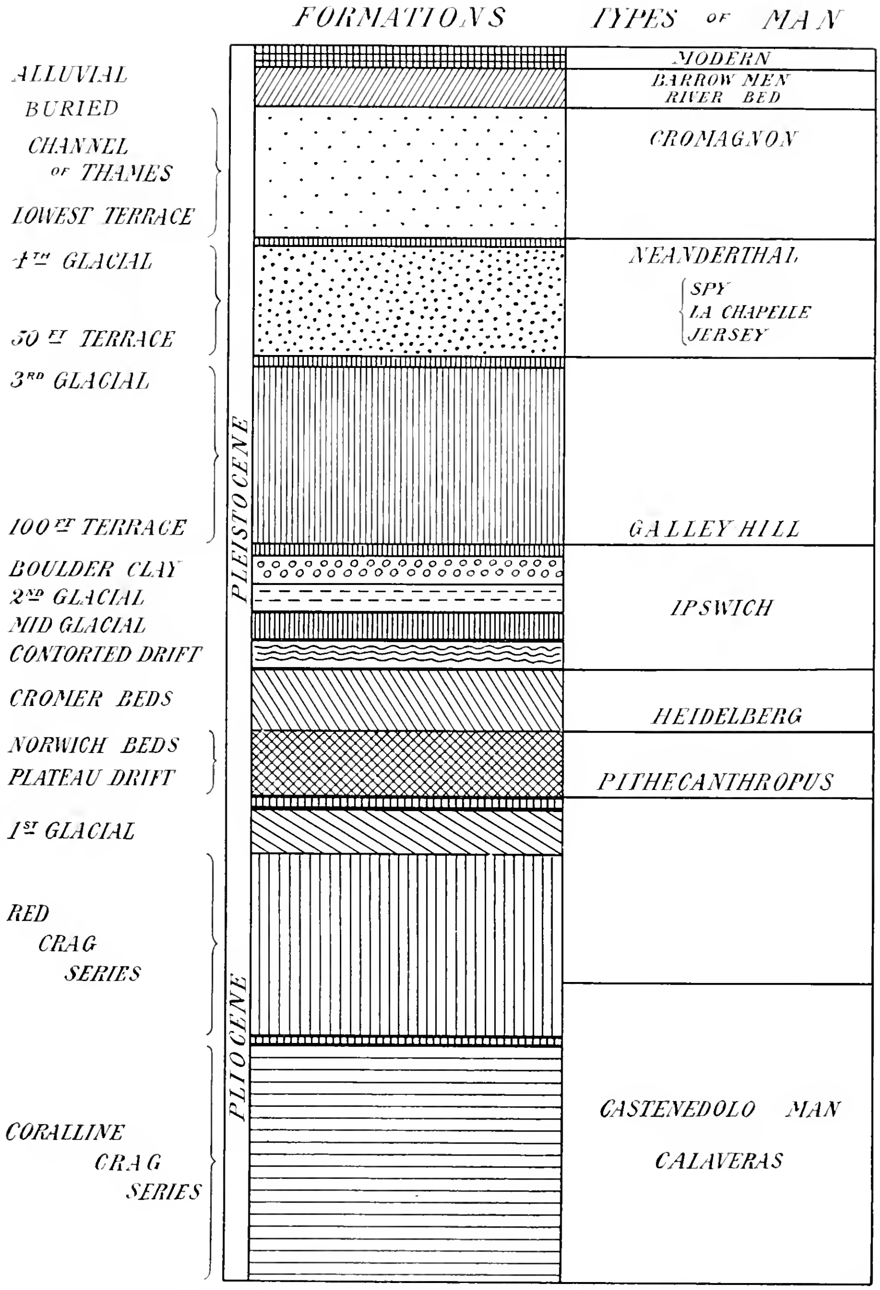
Other features of the man-like apes consist in their having very long arms compared to legs, large superciliary ridges, inclined spinal columns, broad sternums, and no tails. (See Figs. 97 and 98.)

PREHISTORIC MAN

During several generations the mind of man has been endeavouring to trace a resemblance between human beings and apes. Many people have believed in the existence of the so-called "missing link," and have spent much time, labour, and money in attempting to unravel the mysteries of the supposed evolution of man and monkeys from a common ancestral type. In the earlier portion of last century it was impious to distrust the Mosaic story of Creation. In recent times, however, it is abundantly clear that the earth is much more ancient than the years attributed to it in the first chapter of Genesis. Science does not contravert the marvellous narrative as there recorded; as a matter of fact it agrees from the point of view of the order of Creation of living things, but it discounts the accuracy of the supposed age of the Earth, which is there set down as 4000 B.C.

Through various geological periods there have been evidences of Man's existence in many parts of the world. Preceding the historic age, which extends back probably no less than 10,000 years B.C., and dates from the relics of the earliest Egyptian burials, such as those

Fig. 87



A geological chart showing the probable sequence of strata formed in England during the recent Pleistocene and Pliocene epochs. (After Professor Keith.)

exhibited at the British Museum, come the Neolithic and Paleolithic ages, or Post-glacial epoch. Beyond that is the Pleistocene or Quaternary period, beyond that the Tertiary, which includes the Pliocene, Miocene, and Eocene formations, which cover the computed number of 3,000,000 years. In the latter—the Eocene—the relics of an ancient type of lemur have been found.

The Heidelberg Jaw.—The very earliest trace of fossil man yet discovered in Europe is that of the jaw of the Heidelberg man. Geologists appear to be agreed that this relic of stupendous age was laid down in a stratum formed by a river before the first glacial period settled on Europe. The sand-pit where it was discovered, in 1908, is situated in Baden, close to Heidelberg, in the valley of the tributary of the river Neckar. Dr. Schoetensack, of the University of Heidelberg, characterized it as a most important and remarkable find. It was possible, he conceded, to form a conception of the stage of man's evolution in Europe at the junction of the Pliocene and the Pleistocene periods. The main features of the jaw were the massive character of the long framework, which at first sight seemed more anthropoid than human; that the masticatory muscles must have been more highly developed here than in any other known human race; that the parts were ill adapted for the mechanism of speech; that the mental eminence represented the stage in the evolution of the chin from a Simian condition. It was apparent that only a very primitive stage in the evolution of language had been reached. This jaw is believed to have been 1,000,000 years old.

The Neanderthal Skull.—Little has been proved by the discovery of fragments of human bones found in various countries during the last century. The first to which considerable attention was attracted was the Neanderthal skull, unearthed near Düsseldorf in 1856, a few years before the publication of Darwin's "Origin of Species." The relic showed an extremely flattened cranium with largely developed superciliary ridges. Virchow believed it to be that of a deformed type of skull.

Exploration of a cave in the cliffs at St. Brelade's Bay, on the south coast of Jersey, has resulted in the discovery of remains of the very earliest race yet known in Europe—the Neanderthal.

The cave, situated 60 feet above the present beach, was filled and obscured by a surface fall in a long past period, but in more recent times has become exposed by the action of the sea. The exploration which has been carried out by the Société Jersiaise, was suggested by the discovery of a very primitive type of flint implement found in the rubble below the site of the cave. Operations were begun in 1910, and when the floor of the cave was reached, after the removal of 25 feet of overlying material, extensive traces of primitive man were found. Old hearths were indicated by the fragments of charcoal and burnt earth, numerous flint instruments of a very primitive type were found, and bones and teeth of certain extinct animals.

The bones were those of the woolly rhinoceros, the reindeer, and two varieties of horse. The teeth, nine in number, belonged without doubt to an individual of the Neanderthal race, but are in certain features more primitive than even the teeth of the Heidelberg mandible, usually regarded as mentioned above as the earliest remains of man yet discovered in Europe and assigned to the Glacial period.

This is the first discovery of Neanderthal man outside the limits of the Continent of Europe. It is probable that Jersey was united with the mainland when it was inhabited by the Neanderthal type of man.

The Man of Spy.—In 1886, two Belgian professors, Fraipont and Lohest, found at Spy two similar skulls accompanied by portions of a skeleton. It was surmised that they were contemporaneous with prehistoric man, while the cerebral capacities approached more closely that of modern man than of the ape, *viz.*, 1300 c.c. In exceptional instances the greatest human cerebral capacities (*e. g.*, in the cases of Byron and Cuvier) measured 1800 c.c., the mean being 1500 c.c., while the lowest as represented by the aborigines of Australia was 1400 c.c. The cerebral capacity of the skull of an anthropoid ape never exceeds 600 c.c.

In the Spy skulls the third molars were larger than the second, and these than the first, all having three roots.

The Pithecanthropus Erectus.—In 1891, Dr. Dubois brought to Europe, from Java, the skull of a creature belonging to a type which appears to be intermediary between man and ape. It can be placed

in the Pleistocene period, and probably was approximately the same age as that of the Heidelberg jaw. Some months after finding this skull, two enormous molar teeth, and a presumably human femur, were exhumed at a distance of fifteen metres away from the place where the skull had been buried. From the skull and the femur he reconstructed a kind of ape which was exhibited in Paris in 1900. To this he gave the name of *Pithecanthropus erectus*.[2 6] Anthropologists are not in accord as to whether the Dubois discovery was a degenerate human type or superior ape, or an ancestor of man, and are not yet agreed as to the age of the geological stratum in which the bones were lying. It may, however, be placed among the *Simiidæ*.[1]

The Mousterian Relics.—The relics of a human being were found in August, 1908, in a cave at La Chapelle-aux-Saints, in France, which are less problematical in their origin than those already mentioned. That skull and another found in March, 1908, in the cave of Le Moustier, were decided—on account of the nature of the geological strata in which they were interred, together with some bones of the reindeer and bison and chip flints—to belong approximately to the same age as the skulls of the men of Neanderthal and Spy. Of the latter (the Mousterian skull), Professor Reichardt, of Bâle, made a minute examination, when it was seen that the cranium was dolichocephalic in type and remarkable for the thickness of the bones, and possessed marked superciliary ridges; that the forehead receded; and that the mandible was prominent and without a mental eminence and of extraordinary strength.

The Galley Hill Man.—Quite recently a most fascinating series of lectures on "The Fossil Remains of Man" has been delivered by Professor Arthur Keith, of the Royal College of Surgeons, of England. He described the earliest known remains of a human being ever found in England, which was discovered in the undisturbed upper gravel "terrace" of the Thames Valley at Galley Hill near Northfleet.

The approximate antiquity of fossil remains is arrived at by computing that 1000 years must elapse before a river can wear down its bed the depth of one foot. It is extremely probable that the bed of the Thames has been lowered and raised 170 feet since the upper gravel "terrace" was deposited in Post-glacial or Neolithic periods. Hence,

on this basis of computation it may be estimated that the antiquity of the Galley Hill man was 170,000 years. It is amazing to think how ancient is the modern type of man, for although differing in several features, it is, in essence, modern in type—another proof that evolution works exceedingly slowly.

Our knowledge of the physical characters of the inhabitants of Great Britain began with the examination of the Galley Hill man, as just recorded.

The Ipswich Man.—Since then, however, October, 1911, another most important discovery has been made. This was that of a Pre-Boulder clay man in Suffolk, whose skeleton dates back to the beginning of the Glacial age, or perhaps even an earlier period, distant 100,000 years or more.

To the reader this extraordinary revelation is of peculiar interest, as two dental surgeons were called in among other experts to examine in detail the remains and the teeth. The skeleton was lying on its right side, the arms being flexed and legs folded up in the vertebral column—a posture not unlike that adopted for burial of the dead in Neolithic times. He was a tall man, nearly six feet in height, and though the jaws were lost, the isolated teeth were preserved and found to be small in size, very much worn down, not materially different from the modern type of tooth, and totally dissimilar to those of Neanderthal man. The cranium was small and flat and broad in the occipital region. The femora were the same as obtains in Man today, as were also the bones of the forearms and hands. The tibia and fibula, however, had a peculiar shape, and at once distinguished this skeleton from all Neolithic races and from every form of man yet discovered.

The Tilbury Skull.—The next oldest, as far as yet ascertained, is the skull of an individual found in excavating for the Tilbury Docks in 1883, which is probably 30,000 years old.

The portions of this cranium were found imbedded in the sands thirty-four feet below the surface of the ground, under layers of mud, clay, and peat, which were placed alternately, and the size and shape of the head can be accepted as a type of those which prevail in England today.

Other Skulls.—Similar crania have been discovered; one in Derbyshire in a cave, associated with the bones of reindeer, bear, hyæna, etc.—

Fig. 88

The mandible of a man of Britain, dating from 370 A.D. × $\frac{1}{1}$. Viewed from the right side.

Fig. 89

The mandible of a man of Britain, dating from 370 A.D. × $\frac{1}{1}$. Viewed from the left side.

mammals long ago extinct; one in the Cheddar Caves; another in a tumulus in Anglesey; and finally, the almost complete skeleton of a

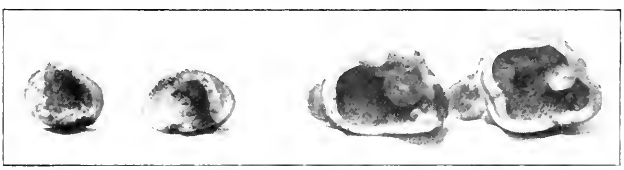
man found in 1910, in an undisturbed prehistoric (Neolithic) stratum, which is being exposed by the encroachments of the sea on the coast of Essex, near Walton-on-the-Naze. An antiquity of at least 4000

FIG. 90

The same, viewed from above. $\times \frac{3}{4}$. The first molar had undergone severe attrition.

years can be assigned to this Englishman. He was a finely made young man, with a stature of 5 feet 2 inches, sharp, prominent nose, and finely moulded face. There was distinct evidence of a specialization in the right arm, pointing to a trade. His teeth were worn flat, and met edge to edge, as in prehistoric races. He evidently died

FIG. 91



Two premolars and two molars from the same, showing great attrition. $\times \frac{6}{5}$.

in the autumn, for within the skeleton were detected over a pint of seeds of the blackberry and dog rose, indicating the form of diet then available.

To come to modern times (circa 370 A.D.), some human bones were recently found in a *tumulus* on the northeast coast of Yorkshire, about two miles southeast of Saltburn, on the edge of a cliff about five hundred and twenty feet above sea level. The *tumulus* contained a fortified Roman outpost, and in the centre was a well, thirteen and a half feet deep. Seven feet from the top of the well the explorers found human remains, of which one (reconstructed) skull has been declared by Professor Keith to be unmistakably British. The coins and pottery found, assign a date of 350–400 A.D. The remains were all placed head downwards. From a dental point of view the jaws and teeth are interesting, especially as their age is specifically that of 1540 years. The molars, as seen in the photographs (Figs. 90 and 91), exhibit much attrition on their enamel surfaces. The angles and sigmoid notches of the mandible vary from those of a more modern type. Through the kindness of Mr. Gerald Marshall, the author has been enabled to examine critically and to photograph these jaws.

THE PRESENT POSITION OF THE THEORY OF HUMAN EVOLUTION

Professor Keith (*British Medical Journal*, April 6, 1912) writes as follow:

"All the evidence indicates a very great antiquity for the later phases in the evolution of the human body. More than forty years ago Sir Charles Lyell expressed his belief that the remains of man would be found in the Cromer beds of East Anglia. Although the actual bones of man have not been found in those beds, flints worked by man's hands have been discovered not only in the Cromer beds, but also beneath a deeper and much older formation—the red crag. Mr. Reid Moir, the discoverer of the pre-crag flints, regards them as being of at least early Pliocene age. The eoliths of the uplands of Kent, although of a somewhat later date than the pre-crag flints, serve better to convey an idea of the time which has elapsed since men first lived on the Kentish plateau. It is a most fortunate circumstance

that these implements were first observed, and their antiquity inferred by the late Sir Joseph Prestwich—a geologist of sound judgment, and conservative in his estimates as regards the past period of man. We owe much to Mr. Benjamin Harrison for the manner in which he has developed our knowledge of these early flints. The deposit or "drift" in which the crudely worked flints or eoliths are found is mixed with fragments of greenstone and chert. The strata from which these greenstone fragments have been washed lie now in the weald five hundred feet below the level of the southern edge of the plateau. Prestwich realized that, at the time these ancient flint implements were imbedded, hills containing the greenstone strata must have occupied the position of the weald, and towered high above the level of the Kent plateau, and that after the greenstone fragments and flint implements were imbedded on the plateau, these hills had been gradually washed away to a depth of at least one thousand feet. The lowlands of the weald have thus been formed since Pliocene man cut the implements now found in the plateau drift. When these facts, and the existence of a primitive form of anthropoid in the earlier part of the Oligocene period, are kept in mind, it becomes possible to believe in the existence of Pliocene man of a modern type—such as Professor Ragazzoni had discovered in the north of Italy.

"Another consideration made anthropologists claim a great antiquity for modern man—in contradistinction to Neanderthal man. Mankind as seen in the world today—European, Mongolian, Red Indian, and Australian—were most diverse in type. Their evolution from a common form demanded the elapse of an enormous length of time. In England we find the types of skulls of her most ancient inhabitants repeated in her modern population. With the exception of the Neanderthal type, all the ancient Continental forms are still to be found in Europe. From predynastic to modern times Professor Elliot Smith found that the skull of the Egyptian has changed only in detail. The oldest human crania found in America are of the Red Indian type. We are forced to believe that human evolution works slowly; yet it has effected the extraordinary contrast seen between two such representatives of the modern type as the negro of Africa and the fair-haired native of North Europe. To accomplish such a degree

of divergence one must carry the history of modern man at least well within the Pliocene period. Of the survivals of ancient human forms, it is very likely that the aboriginal Australian is the best living representative of Pliocene man. From such a type one can understand the origin of the negro on the one hand, and of the European on the other. Neanderthal man was a yet earlier and, in his later development, a yet more aberrant type.

"Two discoveries made in recent years appear to render it impossible to suppose that the modern type of man existed so early as the Pliocene period. The first was the discovery of the Heidelberg jaw in a stratum belonging to the oldest or first stage of the Pleistocene epoch. It was of a most primitive, brutal, and yet human character. It indicates an individual of the Neanderthal type, but of a more massive form than is found at a later date in France. If we accept the Heidelberg individual as typical of the human race of that period (early Pleistocene), then we must suppose that human evolution proceeded at a more rapid rate than we have at present any conception of. We have to remember that in the world today, and it has always been the case, there are types or forms representing very different degrees of antiquity and stages of evolution. It is, therefore, not only possible, but probable, that the Heidelberg and Neanderthal man are survivals of a very ancient type, and in no way indicative of the stage reached by *Homo sapiens* in the Pleistocene period. Using the same manner of reasoning, it is unlikely that the man of Java (*Pithecanthropus*), who was very little older in date than the Heidelberg man, and had a brain capacity of only about half that of modern man, represented the highest type of man of his time. He, too, was evidently a survival of an early stage. At least, it is difficult to believe that in a single and short geological period, even allowing that the extent of that period may be a million years, man could, even in that space of time, double his brain capacity. No parallel instance of so rapid a degree of evolution can be found in the history of Pleistocene mammals.

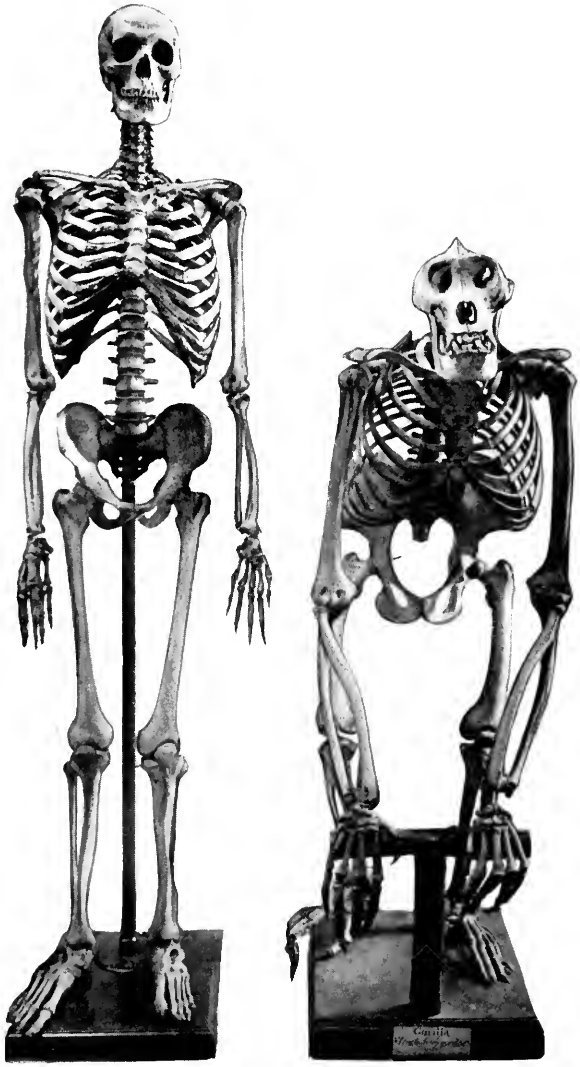
"As regards the degree of relationship between man and the great anthropoids the opinion of scientific men has changed very little since Darwin's time. Huxley regarded the structural difference between man and the gorilla as about equal in degree to that which separated

the gorilla from ordinary monkeys. The divergence between the gorilla and monkey is undoubtedly the greater. It can be safely said that the brain of the gorilla represents an intermediate stage between the brains of man and of the small anthropoid (the gibbon); the brain of the dog-like monkeys represents a still lower or more primitive stage. In 1904, Professor Nuttall confirmed the inferences which anatomists had drawn concerning the relationship of man to anthropoids and monkeys. He established the fact that the blood of the great anthropoids reacts to certain tests in almost exactly the same manner as human blood; the reaction becomes less in amount when the test is applied to the blood of monkeys. The response in the case of those of the Old World is greater than with those of the New, thus bearing out the anatomists' opinion that the Old World monkeys are more recently related to the human stock than those of South America. There is also the evidence of disease. The great anthropoids are susceptible to syphilis—a human disease; monkeys can be inoculated with difficulty. Anthropoids in captivity frequently are liable to typhoid fever; and, when kept in captivity, frequently die from that very human disease—appendicitis. There was no evidence that appendicitis occurred when the anthropoids lived in their native habitats and on their natural diet. Anthropoids are manifestly human as regards the nature of their diseases.

"Although none of the existing anthropoids could be regarded as a human ancestor, there could be no doubt, seeing the extraordinary degree of structural similarity, that man and the great anthropoids were the products of a common stem. The gorilla shows the nearest structural approach to man. (See Figs. 92 and 93.) As to the time at which divergence occurred between the great anthropoid and human lines of descent no definite statement can as yet be made, but to obtain a working hypothesis it is necessary to place the point of divergence in a comparatively remote geological epoch—the Oligocene. The evolution of the great from the small anthropoids may have occurred early in the same period. The genealogical trees which have been constructed to explain the past history of the human stock are as yet little better than crude guesses to explain masses of ascertained facts of anatomy. Further discoveries will certainly cause these genealogical trees to be

modified in detail, yet the sequence of events in the evolution of man's body is becoming clear. The great mass of his brain and his nude

Fig. 92

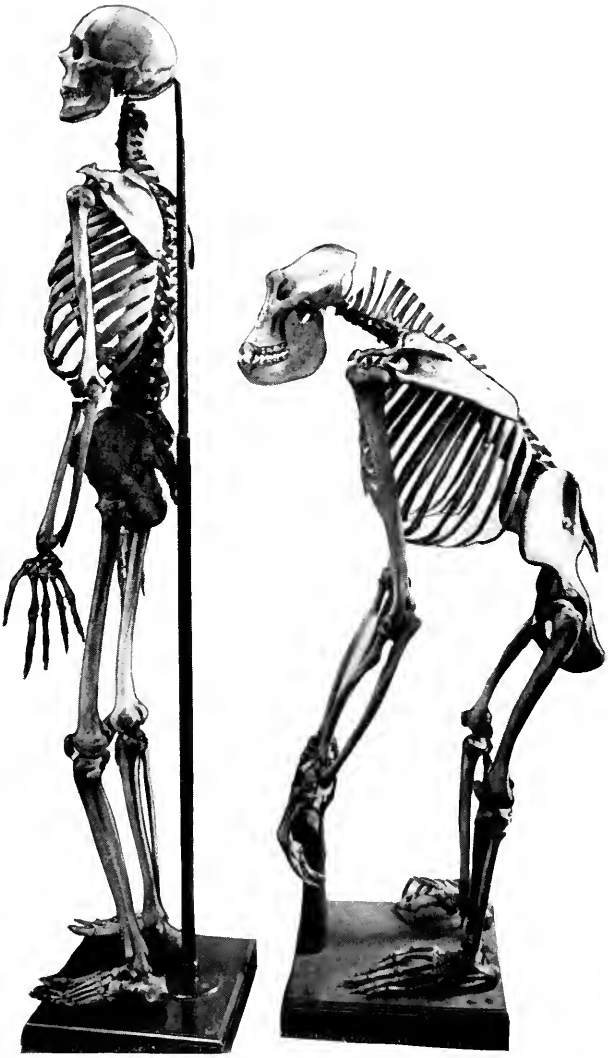


Skeletons of a man and a gorilla (*Gorilla gorilla*) ♀. $\times \frac{1}{11}$. Front aspect.

skin were evidently the latest of human acquisitions; the adaptation of the lower limbs for walking and the modification of his teeth to

their present form were earlier modifications of his structure. The size of his body and his stature were still older human features, while

FIG. 93



The same; side aspect.

the chief structural modifications to adapt the body to an upright or vertical posture, were of very ancient origin."

DESCRIPTIONS OF DENTITIONS

In describing the various dentitions of Mammals it is important to divide the subject into the consideration of

1. The position of the teeth.
2. Their number.
3. Their shape.
4. Their structure.
5. Their implantation.
6. Their succession.
7. The shape, movements, and articulations of the jaws, and
8. The functions of the teeth.

If the above be applied to the typical Mammalian placental dentition, the description would generally read as follows:

1. Implanted in the Premaxillary, Maxillary, and Mandibular bones.
2. Dental formula: I $\frac{3}{3}$ C $\frac{1}{1}$ Pm $\frac{4}{4}$ M $\frac{3}{3}$ x 2=44.
3. Heterodont.
4. Enamel, orthodentine, cementum.
5. Gomphosis.
6. Diphyodont, or rarely monophyodont.
7. Variable shapes and movements.
8. Various functions.

If applied to the anthropoid apes, as follows:

1. Usual position.
2. Dental formula: I $\frac{2}{2}$ C $\frac{1}{1}$ Pm $\frac{2}{2}$ M $\frac{2}{2}$ x 2 = 32.
3. Heterodont, Megadont. (Dental Index = 44). Caniniform second incisor, diastema, etc.,

4, 5, and 6, as above.

7. Ginglymo-arthroidal articulation.
8. Herbivorous generally.

The Orang-outang differs from Man in the following particulars:

1. The absence of articulate language,
2. The feeble type of its intellectual faculties, which are far below even those of the lowest savages, such as the Papuans,

3. The stouter body and more prominent abdomen,
4. The coat of long hair,
5. The extremely small cranial cavity, and ill-developed brain,
6. Long arms, and short legs with prehensile feet,
7. Flattened nose and prolonged nasal septum,
8. Face thrown into many folds, and thick pendulous lips,
9. Jaws prominent (prognathous) and snout-like; facial angle, in adults, 30 degrees; and the mandible incapable of lateral movements, and
10. Its dentition.[5] The teeth exhibit very well the transitional stages in types of pattern. The jaws present a (*A*) Megadont type of dentition, the Dental Index being 55. Maxillary teeth: First incisors are large; the second incisors caniniform; canines are large; first premolars are caniniform; the second premolars are blunter, both having three roots.

    Of the mandibular teeth, the incisors are large, canines large, sexual, and late in eruption, first premolars are similar in shape to canines, but have shorter and blunter crowns, the second premolars possess similar cusps; both these teeth have two roots.

    (*B*) A diastema is present.

    (*C*) The molars increase in size and converge at the back of the mouth.[5]

    (*D*) There is a square dental arch.

    (*E*) Prognathism is marked, the Gnathic Index being over 103.

It is unnecessary to detail the dentitions of the other anthropoid apes.

Generally speaking, the three great divisions of Mankind differ in the standard size and measurement of their teeth. *White* races are microdont, that is, have small teeth. *Yellow*, or Mongolian, races have a mesodont type of dentition, and *Black* races, which include the native aboriginal Australians, a megadont dentition, that is, they possess large teeth.

It has been commonly held that colour was the main distinguishing feature of race. This is probably only partially true. At all events, it would appear that, as prehistoric man can be divided into six distinct racial types, this division can be carried down to the present time, being based upon facial contour and cranial morphology. As in the so-called Anglo-Saxon period there are six types, so in these modern days. It is possible to demonstrate clearly, from the two factors named, *viz.*, cranial shapes and facial contours, that national heterogeneity in ethnic composition depends upon the variations of six patterns. These, as far as the British peoples are concerned, may be known as the Celtic (25.2 per cent.) square faced; Ligurian (20.4 per cent.) pentagonal face; Magian (16.1 per cent.) round face; Iberian (14.4 per cent.) oval face; Remian (12.2 per cent.) pointed, oval face; and Teutonic (11.4 per cent.) oblong face.[9]

The *Microcephalic* races, such as the Native Australians and the Andaman Islanders, possess a cranial capacity of less than 1350 cm., the *Mesocephalic*, Chinese and African negroes, from 1350 to 1450 cm., and the *Megacephalic*, Europeans, Japanese, Esquimaux—over 1450 cm.

A certain standard of measurement must be adopted in determining these differences, by which the sizes of the teeth can be ascertained and measured in their relation to the dimensions of the skull.

Dental Index.—What is known as the Dental Index is used for this purpose.

The Dental Index is the standard of measurement of the relation of the size of the teeth to the dimensions of the skull, and can be ascertained by means of the following formula, the length of the distances being marked out by the help of specially contrived calipers.

$$\frac{\text{The length of the teeth} \times 100}{\text{The basio-nasal line.}}$$

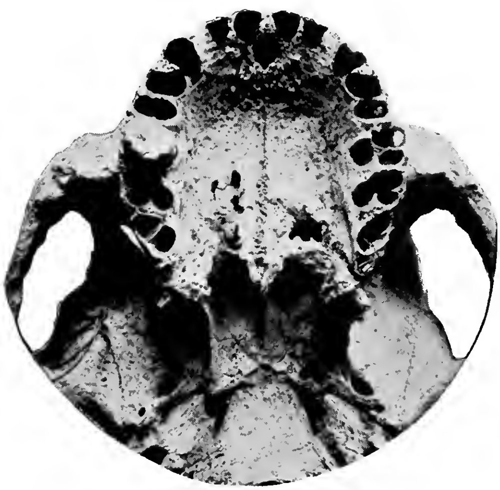
The "length of the teeth" means the distance from the mesial aspect of the first premolar and the distal aspect of the third molar, all *in situ;* the basio-nasal line being an imaginary line drawn from a spot in the middle line of the anterior margin of the *foramen magnum* of the occipital bone (the basion), and the junction of the nasal bones, with

the nasal process of the frontal in the centre of the lower edge of the nasal notch.

It has been found by direct measurement of jaws and skulls that the dental indices of microdont, such as the British, mesodont, such as the Chinese, and megadont races, equal respectively 42, 43, and 44 to 47. In the orang-outang, as already noted, it measures 55.

A diastema means a space, *viz.*, the space existing in each maxilla of certain members of the higher orders of Mammalia. It is a provision on the part of Nature for the accommodation of the mandibular canine, which, in occlusion, on account of its length, passes in front of its maxillary namesake. It thus intervenes between the maxillary second incisor and canine.

Fig. 94



The palatal aspect of the maxillæ of a man of New Guinea showing a diastema between the second incisors and the canines. From a photograph by Dr. W. H. L. Duckworth.

In human skulls it is absent, as a rule, but it may exist. Thus, Dr. Duckworth[1] has described diastemata in the jaws of natives of New Guinea, which are preserved in the Museum of Cambridge University (Fig. 94).

A prognathous animal or human being is one whose upper jaw projects more forward than is usual. The lower races of mankind exhibit this characteristic, *e.g.*, the Australian aborigines, the natives

of certain parts of Africa,[7] of Sumatra,* etc., and approach in type of countenance the chimpanzee or orang-outang.

To obtain this degree of prognathism the facial angle and the gnathic index must be investigated.

Fig. 95

Skull of a native of German East Africa. $\times \frac{5}{7}$. Showing a marked degree of prognathism. *Cf.* Fig. 14.

* A people without any form of religion, without superstition, devoid of any thought of the future state, has been found in the interior forests of Sumatra, according to Dr. Wilhelm Valez, the geologist of the University of Breslau, who has made extensive journeys through the island. There he found the Kubus, as he named them, who are scarcely to be distinguished from the small man-like ape of the Indo-Malayan countries. They are wanderers through the forest seeking food. They have no property. They are not hunters, but simply collectors. They seek merely sufficient nuts, fruits, and other edible growths to keep them alive.

The Kubus wage very little warfare upon the small amount of animal life in their silent and sombre land. The only notion Professor Valez could get from them of a difference between a live and a dead person was that the dead do not breathe. He infers that they are immeasurably inferior to the Paleolithic man of Europe, who fashioned tools and hunted big game with his flint-tipped arrow and knife. Intellectual atrophy is the result of the Kubus' environment. The words they know are almost as few as the ideas they try to express.

Facial Angle.—The Facial angle[4] is an angle contained between two imaginary lines, one drawn from the most prominent part of the

FIG. 96

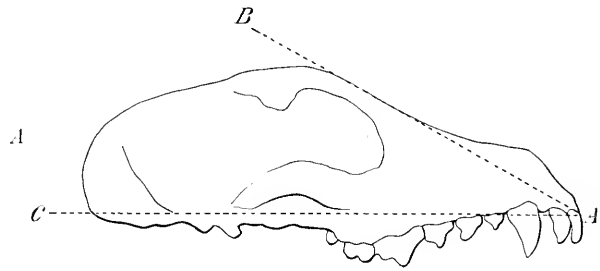


FIG. 97

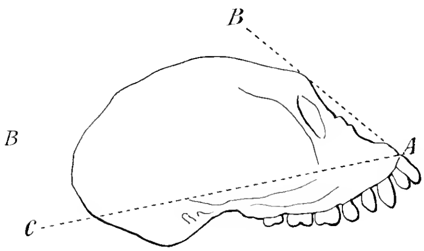
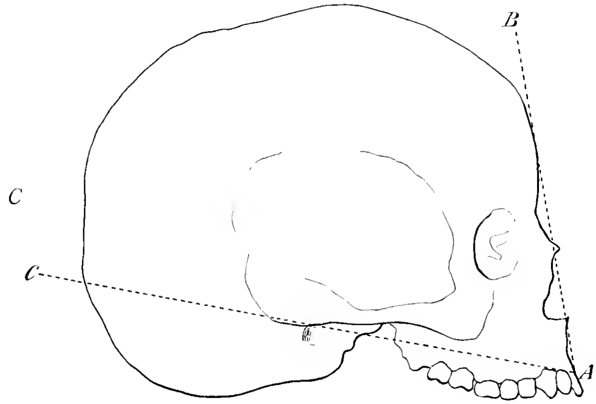


FIG. 98



The facial angles of (*A*) a dog, (*B*) a monkey, and (*C*) a European man, all drawn to the same scale. *A*, the incisive point; *C A*, the basio-alveolar line.

forehead to the prosthion or "alveolar point," that is, the point in the upper jaw which lies on the anterior alveolar margin midway between the two first incisors—and the other, the basio-alveolar line, *viz.*, that extending from the anterior margin of the *foramen magnum*, and the "alveolar point." Prominent jaws indicate an approach to an animal type, especially when associated with a receding forehead, and the greater the amount of prognathism the smaller the facial angle (Figs. 96, 97, and 98).

Gnathic Index.—The degree of projection of the upper jaw is expressed by the *Gnathic Index*, which represents the ratio of the distance between the "basion" and the "alveolar point," to the distance between the "basion" and the "nasal point," that is, the point of junction of nasal and frontal bones in the middle line.

Thus the Gnathic Index is obtained by ascertaining the length of the

$$\frac{\text{Basio-alveolar line} \times 100}{\text{Basio-nasal line.}}$$

Amongst the Greeks the facial angle measured 100 degrees, *i. e.*, the basio-nasal and basio-alveolar lines were equal in length.

At the present day the following measurements obtain:

Race.	Facial angle.	Gnathic index.
Europeans	95 degrees	96
Chinese	..	99
Eskimos	..	101
Fiji Islanders	..	103
Australian natives	85 degrees	104
The dog or crocodile	20 degrees	

Of these—if European races are taken as a type—are, therefore, *orthognathous*, the Chinese; Eskimos and Fijians whose gnathic indices range from 98 to 103, would be *mesognathous*, and Australian aborigines *prognathous*, *i. e.*, 103 or more.

In conclusion, the systematic descriptions of the dentitions of a *European man* would read thus:

1. Position on Maxillary and Mandibular bones.
2. Dental formula: I $\frac{2}{2}$ C $\frac{1}{1}$ Pm $\frac{2}{2}$ M $\frac{3}{3}$ x 2 = 32.

3. Heterodont. Incisors similar in shape. I^2 rather smaller than I^1. Canines more sexual, rather larger than incisors, premolars single rooted except Pm^1; molars decrease in size posteriorly, the third molar being often unerupted.
4. Enamel, ortho-dentine, cementum.
5. Gomphosis.
6. Diphyodont.
7. Horse-shoe shaped, movements varied, ginglymo-arthrodial joint. Orthognathous (95 to 98 Gnathic Index). Facial angle, 95 degrees; microdont, Dental Index, 42.
8. Omnivorous.

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CHAPTER X

THE ANATOMY OF THE TEETH OF MAN

Introductory.—General Considerations.—Descriptions of the Permanent Incisors, Canines, Premolars, and Molars, their Measurements, Variations of Mensuration, Coronal Surfaces, Necks, Roots, Dates of Calcification, Pulp Chambers and Root Canals, Means of Identification, and Surgical Anatomy.—The Deciduous Teeth.—Age Changes.

Introductory.—It is necessary at the outset of writing a description of the human teeth to postulate that by virtue of the operation

FIG. 99

The left maxilla and mandible of an adult, showing the outer aspects of the permanent teeth. $\times \frac{1}{1}$. *Cf.* Fig. 100.

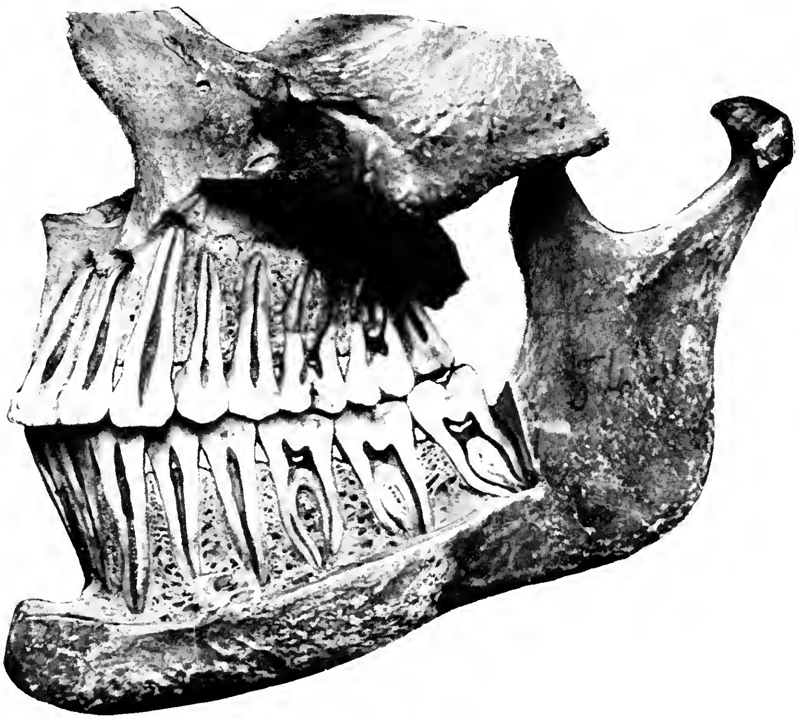
of the law which renders an individuality, which can be estimated on careful scrutiny, peculiar to each bone or muscle or viscus, there are no two dental organs which possess exactly similar morphological

PLATE I

A Human Skull in Norma Facialis. $\times \frac{1}{1}$

characteristics. There are no two teeth identical in every particular; there are no two dental arches or hard palates alike. This fact, if thoroughly elaborated, might be turned to great advantage by criminologists and others who, by means of plaster casts of the teeth and jaws, would probably have a good and sure adjunct to the methods of the identification of offenders against the law by means of finger prints.

Fig. 100



Vertical section through the left maxilla and mandible of an adult, with the external alveolar plates removed to show the general arrangements of the roots of the permanent teeth, the shapes, sizes, and positions of their pulp cavities, and the cancellous character of the bone of their sockets. × 1/1.

Hence, an account of the gross anatomy of the teeth of man must apply only very generally to what obtains in a majority of the specimens examined. Types only can be detailed; perfect examples are almost impossible to find. So many teeth which are described have undergone slight variations of pattern or age changes which are apt

to deceive the observer, and render nugatory any anatomical points on which he is likely to lay a certain amount of emphasis. The same may be said regarding the illustrations. No outline drawing of a tooth can represent its real architecture. The reader is begged, therefore, to bear in mind that the narration which now ensues is, at best, merely an attempt to portray verbally and visually its most important particulars.

General.—A tooth consists of a crown, a neck, and a root or roots. Of these the former usually presents above the gum, the latter is implanted in an alveolar socket, and the neck is the region which intervenes in the neighbourhood of the gingival trough. If a tooth remains, however, imbedded in the substance of the bone of the jaw, it still generally possesses these three main parts (Figs. 5 and 6), although, if its non-erupted condition should have induced a cyst of the jaw—whether it be a dental cyst, a follicular odontome or an odontocele—one or more of these parts may be absent. Teeth erupting in anomalous situations, such as the floor of the nasal fossæ, the exterior of the cheek, the interior of the antrum, the surface of the ill-formed bone found in certain teratomata, etc., may also possess these parts in a modified degree. (See Figs. 3 and 4.)

For graphical purposes the writer proposes to relate the anatomical characteristics, first, of the maxillary permanent series of the right side, then the mandibular teeth, and then the chief distinguishing features of the members of the deciduous dentition also of the same side.

THE MAXILLARY SERIES

The Incisors.—The incisors (*Incidere*—to cut into) are eight in number, four maxillary and four mandibular. They are called the First and Second, or clinically and vulgarly the "central" and "lateral." They are the teeth which are implanted in the premaxillary bone in the upper, and the corresponding members in the lower jaw. Their crowns roughly resemble the ivory mouth-piece of a flute. They possess one root and one pulp canal. Occasionally, there may be traces of a second root.

The First Right Maxillary Permanent Incisor.—This tooth is situated on the right of the midline of the face, that is, to the right of that part of the palatal process of the right superior maxillary bone which articulates with the left superior maxillary bone. In France it is popularly termed "*la palette*" (the battledore), by reason of its shape and of its size being greater than that of the second incisor.

(*a*) MEAN MEASUREMENTS.—The extreme length from incisive edge to apex of root is 25 mm.; extreme width across the broadest part of the crown is 9 mm. It is usually a very large tooth. Black gives in his "Dental Anatomy" the following figures: Average length of crown, 0.39 inch; of root, 0.49 inch; of length over all, 0.88 inch.

Variations of mensuration range, in rare specimens, from 14 mm. to 32 mm. in extreme length, and 5.75 mm. to 10 mm. in extreme width.

(*b*) CORONAL SURFACES.—The coronal Surfaces are four in number, and there are two angles.

(*i*) *Labial Surface.**—It measures in extent 9 mm. by 12.5 mm. Triangular in shape, its base is at the incisive edge. It is convex from above downward and from side to side. It terminates at the gingival margin by a rounded border slightly raised from the neck, and curving downward on the mesial and distal surfaces, approaches the incisive edge very considerably. Thus the upper border of a labial surface which is 12.5 mm. in a vertical direction from the incisive edge is only 8 mm. on the mesial surface.

It is smooth and shiny in appearance, and in the majority of cases its surface is somewhat broken up by numbers of small longitudinal or horizontal grooves (imbrication lines), which represent an imperfected condition of the enamel. This remark applies to the enamel of the other teeth generally.

(*ii*) *Lingual Surface.*—This is more triangular in outline than the former, though its edges are more rounded. It is concave from above downwards and also from side to side, but the vertical concavity does

* In France anatomists allot different names to the coronal surfaces. Thus the "anterior" and "posterior"[2] aspects correspond to the labial and lingual surfaces of incisors and canines, and to mesial and distal surfaces of the premolars, while the buccal is the "external" and the palatine is the "internal" or, according to Barden[1] and Dieulafé and Herpin,[5] the "vestibular" face.

not extend to the cutting edge or lower border which runs in a straight line. In many incisors there is evidence of a slight elevation of an aborted cingulum on the upper border of these two surfaces, which shows itself as an inconspicuous prominence in the central axis of the tooth.

(*iii*) *The Mesial surface* is smaller than the distal. It is slightly convex in both directions. Triangular in outline, the apex is placed below, the base being largely encroached upon by a second triangle formed by the cementum at the neck of the tooth.

FIG. 101

FIG. 102

FIG. 103

FIG. 104

FIG. 105

FIG. 106

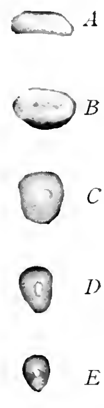


FIG. 101.—The maxillary first incisor—Labial aspect. $\times \frac{1}{1}$.
FIG. 102.—The same—Lingual aspect.
FIG. 103.—The same—Mesial aspect.
FIG. 104.—The same—Mesio-distal section.
FIG. 105.—The same—Labio-lingual section.
FIG. 106.—The same—Various horizontal sections: *A*, through the crown; *B*, through the crown; *C*, the neck; *D*, mid-portion; *E*, near the apex.

(*iv*) *The Distal surface* is also triangular with the same encroachment of the cervical triangle; the distance, however, between the apices of these two triangles is greater on the latter than on the former surface, the measurements being mesially 7 mm.; distally, 8.5 mm.

(*v*) *The Angles*.—The mesial angle is a right angle, at times rather more than a right angle; the distal is an obtuse angle.

Newly erupted incisors generally possess three tubercles on the cutting edge which, for some unexplained reason, disappear in a normal physiological manner as the years pass by.

(*c*) NECK.—The Neck of the tooth is formed by the convergence of the four surfaces, and is represented by their upper borders. It does not lie in the same horizontal plane throughout, but, as already

mentioned, dips down mesially and distally at spots situated midway between the labial and lingual surfaces.

(*d*) Root.—The Root is cone-shaped, and nearly cylindrical. Its greatest circumference is not at the neck, but about one-third of the distance between the neck and the apex. Its sides are not equally convex nor straight. The mesial aspect is the most convex, and at the same time it is the most vertical, the distal aspect being the most flattened and curved. It generally tapers gradually to its extremity, which is frequently curved or deflected, and, in a great many cases, roughened and enlarged by a deposit of lacunated cementum. The apical foramen which transmits the afferent and efferent bloodvessels and terminations of the nervous system of the pulp is generally clearly marked. But it is often most difficult to see and its orifice so occluded as to admit of no passage of the finest bristle which could possibly be manufactured.

(*e*) Calcification.—The Calcification of this tooth begins, according to Norman Broomell,[5] in three centres of ossification, in the first year *post natum*, and is completed as far as its outer appearance is concerned by the tenth to the eleventh year, and eruption begins about the seventh year and ninth month (30.5 *per cent.*), according to James and Pitts.[12]

(*f*) Pulp Canal.—The Pulp Canal, as seen in the labio-lingual direction, conforms closely to the general shape of the tooth. At the tenth year it resembles two narrow cones, the bases of which are placed on a level with the cervical region of the tooth, the upper or radicular cone being the larger and the narrower. Mesio-distally, the lower edge of the pulp cavity is the broadest part, follows the same direction as that of the cutting edge, has up to the fifteenth year three cornua—of which the central is the least marked, and disappears about that age—the others, named mesial and distal respectively, remaining up to old age.

Transversely the pulp canal is almost cylindrical in outline.

(*g*) Identification.—Identification of this incisor may be effected by the following means: If the tooth is held in a horizontal position between the left forefinger and thumb, with the convex surface of the crown lying upwards and the root away from the spectator, the

sharper angle of the cutting edge will point to the side to which it belongs.

(*h*) Surgical Anatomy.—Subgingival tartar may collect on the mesial and distal aspects of the cervical region of the root. Caries begins most frequently interstitially; that is, on the mesial aspect. Black,[6] who has most thoroughly investigated and charted the positions of dental caries, gives the following percentages: *Labial* surface, 3.2; *Lingual*, 2.6; *Mesial*, 31.6; *Distal*, 26.3, and *Mesial* edge, 1.5. Magitot's computation is that 6 *per cent.* of the superior incisors are carious.

In England it is generally believed that the first permanent molar is most frequently a victim to caries.[11] In this connexion the reader must compare Black's figures regarding this tooth. When treating diseases of the pulp, the chamber should be opened by drilling through the enamel and dentine in the centre of the lingual surface, in the direction of the long axis of the tooth. An alveolar abscess connected with this tooth, points over the external alveolar plate above the apical region. Rotation of the root is indicated in the operation of extraction. In orthodontics the thinness of the external alveolar plate allows with facility the forward advancement of the teeth. Fusion of this with the following tooth sometimes occurs (true gemination), and extremely rarely with its fellow of the opposite side (false gemination). It is frequently hypoplasic; or congenital syphilis leaves its mark in the form of a notch on the incisive edge, and a general dwarfing of the crown.

The Second Right Maxillary Permanent Incisor.—In external configuration it is approximate to that of the first incisor. It is a smaller tooth in every respect and its architecture is not so well pronounced. It is frequently suppressed (Figs. 43 and 44).

(*a*) Mean Measurements.—Extreme length, 23 mm. Extreme width, 6.5 mm. According to Black: Average length of crown, 0.34 inch; of root, 0.51; length over all, 0.85 inch.

Variations of mensuration, 31.5 mm. to 18 mm.; 7 mm. and 55 mm.

(*b*) The Crown.—The extent of the (*i*) *Labial Surface* is 10 mm. x 6.5. mm. It is more convex in both directions than its neighbour, and the upper border is less rounded. Its surface is smooth, often less

scoured by lines of minute pits or fissures than the first incisor, and approximates more closely to the shape of an isosceles triangle than the other. The incisive edge often presents two small tubercles which may remain till the eleventh year.

(*ii*) *The Lingual Surface* is more extensive vertically than the former. Then it may measure 1.5 mm. more in depth from above downwards. Its concavities are very marked and the cingulum is often raised at the gingival margin into a large prominence.

FIG. 107

FIG. 108

FIG. 109

FIG. 110

FIG. 111

FIG. 112

FIG. 107.—The maxillary second incisor—Labial aspect. $\times \frac{1}{1}$.
FIG. 108.—The same—Lingual aspect.
FIG. 109.—The same—Distal aspect.
FIG. 110.—The same—Mesio-distal section.
FIG. 111.—The same—Labio-lingual section.
FIG. 112.—The same—Various horizontal sections: *A*, through the crown; *B*, the neck; *C*, the root; *D*, near the apex.

(*iii*) *The Mesial* and (*iv*) *Distal Surfaces* closely approach one another in size and shape. While the former is flat and only slightly convex, the latter is particularly well rounded. The *mesial* angle is obtuse, the *distal* angle rounded and still more obtuse.

The longitudinal axis of the tooth is in a straight line, the position of the radicular apex occupying a plane which passes through the centre of the tooth and joins the incisive edge midway between the two angles.

(*c*) NECK.—The v-shaped outline of the Neck is not so marked as in the first incisor. The cingulum varies very greatly and at times may be duplicated.

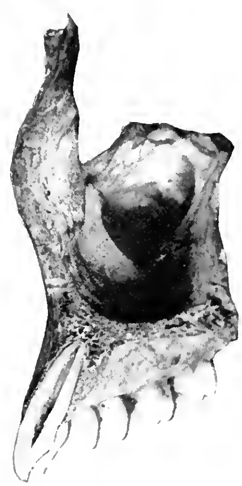
(*d*) ROOT.—The Root is cone-shaped, but considerably flattened from side to side. It may be bifurcated. Its mesial and distal aspects are much broader than the labial and lingual, the proportion of the

two being as 4 is to 6. The apex is frequently deflected to one or other side, most often towards the distal. As in the first incisor, the apical foramen is most frequently so small as to be indiscernible.

(*e*) Calcification.—The Calcification begins during the first year *post natum*, and is superficially completed by the tenth to the eleventh year, eruption taking place between the ninth year and third month in 35.4 per cent. of cases.[14]

(*f*) Pulp Canal.—The Pulp Canal of this tooth is, relatively to the size of the tooth itself, greater than that of the first incisor. It follows, therefore, that it is very little smaller than that which obtains in the neighbouring tooth, and that its dentinal and enamel coverings are naturally thinner. The cornua are similar to those already described, a central one may be present, but the mesial cornu may be a little more elongated than the opposite one.

Fig. 113



Labio-lingual section through a maxillary incisor, *in situ*, to show the osseous relationships. $\times \frac{1}{1}$.

(*g*) Identification.—Identification of this incisor may be effected by similar means to that employed for the first incisor. The sharper angle of the cutting edge points to the side to which it belongs.

(*h*) Surgical Anatomy.—Caries affects the various surfaces as follows: Labial, 1.6; Lingual, 0.6; Mesial, 28; Distal, 15.5; Incisive edge, 1.3 *per cent.*, and on any surface 7.4 *per cent.* The pulp chamber must be opened similarly to that already previously described. An abscess found in connexion with this tooth extends into, and opens over, the side of the palate, by reason of the fact that, when *in situ*, the apex of the root has a tendency to look inwards towards the central line of the hard palate. Dental cysts arise frequently from this tooth in the proportion of 1 to 10.

The Canines.—The canines are four in number, situated at the angle of the alveolar processes of the jaws, and on account of their position are valuable agents in maintaining the character of the face, and imparting to their possessor, according as they are large and promi-

nent or not, a bestial or beautiful aspect of countenance. From this æsthetic point of view, therefore, they constitute the most important of all the teeth of Man. They are called canines from their large size and cardinal function in the *Canidæ*, their prominence being clearly and obviously noticed in the members of the carnivorous type of animal. The maxillary canines are designated "Eye teeth" by the ignorant and uninformed, this antiquated* and incorrect term appearing to arise from the widespread belief that ocular disturbances very often took their origin from these teeth.

Those situated in the maxillæ are the teeth which, placed in those bones, erupt beyond the intermaxillary suture, provided they are not too far behind. They are readily distinguished by their great length, and dimensions, which surpass every other member of the dental series.

The Right Maxillary Permanent Canine.—(*a*) Mean Measurements.—Greatest length, extending from apex of root to the extremity of the cusp, is 27 mm., width in coronal region 8 mm. It is usually a very large tooth, and is infrequently missing from the dental arch.

Black's measurements are: Average length of crown, 0.37 inch; of root, 0.68 inch; total length, 1.05 inches.

Variations of Mensuration: 8 to 38 mm. in length and 5.5 to 9 mm. in width.

(*b*) Crown.—The Crown is somewhat cone-shaped, with a morphological modification, chiefly on the distal side. It has four surfaces, labial, lingual, mesial, and distal.

(*i*) The *Labial Surface* is very convex, the most prominent part being at the junction of the lower two-thirds with the upper third. The upper border is almost on a level with the root surface, the lower border, sharp and pointed, is shorter on the mesial than on the distal side. This surface is divided into two unequal parts by a ridge of enamel, the direction of which more or less coincides with the longitudinal axis of the tooth, of which the mesial side slopes off gradually in a convex fashion, to the mesial surface of the tooth, while the other may even be slightly concave, or at all events, flattened. In some speci-

* To Galen (131 A.D.) is credited the belief that these teeth receive branches from the nerves which supply the eyes.

mens it is distinctly grooved from above downwards, one on either side of the median ridge. The ridge terminates at the cusp of the tooth. The lower border of the surface is pointed at the cusp and runs mesially, to end in a slightly obtuse angle, and, distally, in an extremely obtuse angle.

FIG. 114

FIG. 115

FIG. 116

FIG. 117

FIG. 118

FIG. 119

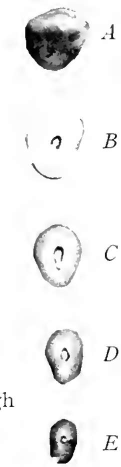


FIG. 114.—The maxillary canine—Labial aspect. × 1/1.
FIG. 115.—The same—Lingual aspect.
FIG. 116.—The same—Mesial aspect.
FIG. 117.—The same—Labio-lingual section.
FIG. 118.—The same—Mesio-distal section.
FIG. 119.—The same—Various horizontal sections: *A*, through the crown; *B*, through the crown; *C*, the neck; *D*, the root; *E*, near the apex.

(*ii*) *Lingual Surface.*—This is more triangular than the preceding. It is concave from side to side and from above downwards. Like the preceding, it is roughly divided into two parts, by a vertical ridge of enamel, having on either side a rounded hollow, the depth and extent of which varies very greatly in every subject. The upper and lower ends of this enamel edge terminate in prominent elevations, of which the former is the middle portion of the cingulum, the other the thickening of the cusp of the tooth itself. There is a slight elevation of the mesial and distal borders into crests.

(*iii*) *The Mesial Surface* is flattened from before backwards, and from side to side. It is less triangular in outline than that of the first incisor, and the crown of the tooth passes almost imperceptibly into the neck and root, the junction being very nearly in a straight horizontal line.

(*iv*) *The Distal Surface* is similar to the preceding, but at its lower portion, at the junction of the distal part of the lower border, a

considerable amount of thickening of the crown occurs, and gives the characteristic appearance to the maxillary canine.

(*v*) *The Angles* are obtuse, the distal being markedly so, and very blunt and rounded.

(*c*) Neck.—The Neck is ill defined, the enamel gradually becoming thicker as it approaches the cusp of the tooth. In some specimens the neck is only distinguished by the differences in appearance of the enamel and cementum.

(*d*) Root.—The Root is a laterally flattened cone. Its remarkable length has already been alluded to. Across its mesial or distal aspect it may measure 8 mm., across the labial 5 mm., and across the lingual 4 mm. Sometimes these broader surfaces exhibit traces of a groove and become in that respect, somewhat premolariform in character. Its apical region is often deflected.

Fig. 120

Labio-lingual section through a maxillary canine, *in situ*, to show its osseous relationships. $\times \frac{1}{1}$.

(*e*) Calcification. — Calcification begins during the third year after birth, and is superficially completed from the twelfth to the thirteenth. Its eruption precedes its completion of calcification and occurs about the tenth year and sixth month.

(*f*) Pulp Canal.—The shape of the Pulp Canal follows closely the exterior aspect of the tooth. Transversely, the outer half is broader than the lingual portion.

(*g*) Identification.—This can be accomplished by the same means as for the incisors. By taking into consideration the location of the prominence on the distal surface of the crown, it is always easy to ascertain to which side of the mouth the tooth belongs.

(*h*) Surgical Anatomy.—The apical foramen is closed, generally speaking, at the time of, or immediately after the eruption of, the tooth. This tooth is, of all, the least frequently missing, and the most frequently misplaced in the dental arch, either erupting high up

in the external alveolar area, or inside the line of the neighbouring teeth. It often remains embedded in the jaw in an encysted or normal condition, and adopts an oblique or a horizontal position in the bone (Fig. 5 and 6). Once fully grown and completely in place, the position of the maxillary canines varies less frequently, and to a less extent, than any other tooth, as a result of changes in the jaw.

The Percentage of Caries.—The interstitial surfaces are more frequently attacked than the self-cleansing surfaces. Caries of the cusp is not very rare. Black's figures are: Mesial caries, 16; Distal, 11; Labial, 1.6; Lingual, 0.6, and cutting edge, 1.8. Magitot's figures are, for any surface of the whole tooth, 4.4 *per cent.*

The Maxillary Premolars.—Each maxilla possesses two premolars, and on either side of the mandible there is also the same number. They are the fourth and fifth teeth from the midline, and occur between the canine and the molars. They replace the molars of the deciduous dentition. They are the homologues of the third and fourth premolars of the typical mammalian dentition.

The synonym "bicuspid," although it has passed for many years into common daily parlance, is not absolutely correct, because many other teeth possess two cusps. It is advisable to be strictly accurate, and to speak of this tooth as a premolar, which signifies that it is placed in the dental arch in front of the molars, and that it has had a molariform predecessor.

Some authors aver that the premolar represents a fusion of two primitive haplodont cones, as has been explained in Chapter VIII. This is probably erroneous, as it would imply a lateral fusion of two distinct and different dentitions, of which the rate of growth would be nearly equal. The inner cusp may be considered as an elevation of the inner portion of the cingulum.

The First Right Maxillary Premolars.—(*a*) MEAN MEASUREMENTS.—Extreme length, 20 mm.; extreme width, 6.5 mm. Length of crown, 0.32 inch; or root, 0.48 inch; total length, 0.80 inch.

Variations of Mensuration.—The largest may equal 28.5 mm. in extreme length, and 8 in extreme breadth, and the smallest 13 mm. in extreme length by 6.5 in extreme width.

(*b*) CROWN.—The Crown presents five surfaces for examination: (*i*) Labial; (*ii*) lingual; (*iii*) mesial; (*iv*) distal, and (*v*) morsal or occluding.

It is roughly cuboidal in shape, the internal or lingual portion being slightly the smaller of the two.

FIG. 121

FIG. 122

FIG. 123

FIG. 124

FIG. 125

FIG. 126

FIG. 121.—The maxillary first premolar. Distal aspect. $\times \frac{1}{1}$.
FIG. 122.—The same—Mesial aspect.
FIG. 123.—The same—Buccal aspect.
FIG. 124.—The same—Bucco-lingual section.
FIG. 125.—The same—Mesio-distal section.
FIG. 126.—The same—Various horizontal sections: *A*, through the crown; *B*, through the crown; *C*, through the crown; *D*, the neck; *E*, the roots; *F*, the apices.

(*i*) The *Labial* surface is convex from above downwards, and from side to side. Very striking in its resemblance to the corresponding surface of the crown of the canine, it often presents the median ridge and lateral vertical grooves described in dealing with that tooth. The difference lies mainly in the fact, that here the grooves are not entirely vertical, but converge somewhat at the lower border. The outline of this surface is less triangular than that of the other anterior teeth, becoming more diamond-shaped. The point of the cusp is sharp, but rounded on the morsal surface.

(*ii*) *Lingually* viewed, the surface is very convex in both directions, and possesses no vertical ridge or grooves. The superficies is considerably less than that of the former.

(*iii*) *Mesial*.—This surface is roughly quadrilateral in outline, the lower portion being slightly protuberant. It is slightly concave in

both directions, and the vertical concavity may amount sometimes to a grooving.

(*iv*) *Distal.*—Similar to the preceding except for its convexities. It is probably relatively larger in area, and the prominence of the lower portion more pronounced.

(*v*) *The Morsal Surface* is of the shape of an irregular trapezoid. The greatest diameter is in the labio-lingual direction on account of its lateral flattening. As a result of a slight convergence of the mesial and distal surfaces, the labial surface is the largest of the three. Its angles are very rounded and turned towards the centre of the tooth. Of the cusps, the outermost is the larger, and is separated from the other by a deep sulcus. It is surmounted by four ridges or crests of enamel, which uniting to form the prominence of the outer cusp, pass, one forwards to the outer mesial angle, the second backwards to the outer distal angle, the third inwards to the middle of the sulcus, and the fourth, indistinctly to unite outwards, with the median ridge of the enamel on the labial surface. The lingual cusp is less prominent, its point less pronounced, and more rounded. Like the other, ridges of enamel pass outwards, forwards, and backwards. The floor of the morsal surface is traversed by certain additional grooves, often amounting to fissures, which, crossing in a mesio-distal direction, may bifurcate near either extremity, and pass outwards and forwards, or simply turn outward.

(*c*) NECK.—The Neck is nearly horizontal, and dips down very slightly on the mesial and distal surfaces.

(*d*) ROOT.—The Root is very flattened from side to side, and presents on its mesial and distal aspects a deep grooving, which is often sufficiently pronounced as to divide into two roots, each having a pulp canal. The groove on the mesial aspect is greater than the other. It is probable that the first premolar is undoubtedly bi-rooted in almost 60 *per cent.* of cases. The roots may be joined through only half their length, though the usual condition is to find them united through two-thirds, or even five-sixths, of their length. Rarely, three roots may be present, in which case two are labially, and the other lingually placed, an anomaly which probably is atavistic, as three-rooted first premolars are constant in the *Anthropoidia*, as described

in Chapter IX. There is a great tendency for the roots to diverge at their apical regions.

(*e*) CALCIFICATION.—Calcification begins about the fourth year and is superficially completed about the eleventh to the twelfth. The tooth is erupted between the ages of nine years, and nine years and six months.

(*f*) PULP CHAMBER.—The Pulp Chamber closely imitates the outlines of the crown. There are two cornua, each of which projects into the buccal and the lingual cusp, the former being the larger of the two. On account of the excessive lateral flattening of the tooth, the greatest diameter of the pulp canal occurs in a labio-lingual direction. There are two pulp canals, the bifurcation of the pulp chamber occurring in the immediate neighbourhood of the neck of the tooth.

(*g*) IDENTIFICATION.—The Identification of this tooth may be accomplished by holding the tooth with its crown towards the observer, and its larger external cusp pointing in the same direction. The deeper grooving of the root—on the mesial or canine aspect—points towards the side to which the tooth belongs.

FIG. 127

Labio-lingual section through a maxillary first premolar, *in situ*, to show its osseous relationships. $\times \frac{1}{1}$.

(*h*) SURGICAL ANATOMY.—In opening up the pulp chamber or canals, the point to select, is in the centre of the chief groove on the morsal surface. Care must be taken in this operation, or the roots may be split. Caries affects this tooth most frequently on the distal surface, least frequently on the lingual, as the following figures (Black) show: Mesial, 12.6; Labial, 1.3; Distal, 20; Lingual, 0.1; Morsal, 6.6. Out of Magitot's 10,000 cases, the first maxillary premolar was carious 949 times, giving a percentage of 9.4. For the prevention of overcrowding and irregularity in the position of the teeth, the extraction of this tooth before eruption is undertaken with successful results. It is necessary, however, before removal of the deciduous molar, to ascertain by means of the *x*-rays, whether the tooth is present or not.

The Second Right Maxillary Premolar.—This tooth is the fifth in the series from the maxillary suture. It closely resembles the morphological features of the first premolar, but differs mainly in two particulars. It is very slightly smaller, its alveolar parts are confluent, and give it the appearance of possessing only one root. There may be two pulp canals present. Its cusps are often shorter and the ridges more rounded than in the first premolar.

(*a*) Mean Measurements.—Extreme length, 22 mm.; extreme width, 5 mm.

Variations of Mensuration.—The largest examined was 28 mm. in extreme length and 8 mm. across the broadest part of the crown in a mesio-distal direction, the smallest 16 mm. and the same width.

Fig. 128

Fig. 129

Fig. 130

Fig. 131

Fig. 132

Fig. 133

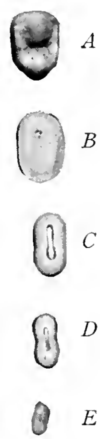


Fig. 128.—The maxillary second premolar. Mesial aspect. $\times \frac{1}{1}$.
Fig. 129.—The same—Distal aspect.
Fig. 130.—The same—Buccal aspect.
Fig. 131.—The same—Bucco-lingual section.
Fig. 132.—The same—Mesio-distal section.
Fig. 133.—Various horizontal sections: *A*, through the crown; *B*, through the crown; *C*, the neck; *D*, the root; *E*, the apex.

Black's figures are: Average length of crown, 0.29; of root, 0.55; total, 0.84 inch.

(*b*) The Crown.—(*i*) The *Labial Surface* is convex in both directions, but not so much as in the first premolar. It is widest across the middle portion of its surface. The upper border is less curved than in the former. The cusps are more equal in their dimensions.

The convexity of the (*ii*) *Lingual* surface is marked; the borders and angles are rounded.

The (*iii*) *Mesial* and (*iv*) *Distal* surfaces are not parallel, but have a tendency to slope upwards towards the root.

The (v) *Morsal* surface closely resembles that of the first premolar. In fact, it is often extremely difficult to determine the difference between the two, on regarding the masticating surface alone. The elevation of the cusps is nearly identical. The labial and lingual edges are almost of the same size. The central sulcus is less deep than in the first premolar, and does not extend so far forwards or backwards as in that tooth.

(*c*) NECK.—The Neck is practically indistinguishable. Its situation can, however, be determined by the position of the free margin of the enamel. The plane occupied by the cervical margin is horizontal.

(*d*) ROOT.—The Root is a little longer, rather smaller and more flattened from side to side than the first premolar. It may be bifurcated and possess two pulp canals, one buccal and one lingual. It is straight, and is always in immediate relationship with the floor of the antrum of Highmore, frequently piercing it. The anterior groove is often absent, and it is generally less conspicuous than that on the distal aspect.

(*e*) CALCIFICATION.—Calcification begins during the fifth year after birth, and is superficially completed by the eleventh or twelfth. The tooth begins to erupt about the tenth year and third month.

(*f*) PULP CHAMBER.—The Pulp Chamber is, in outline, similar to that of the tooth itself. The cornua are less accentuated than those of the first premolar. The root canal is single, as a rule, and very flattened from side to side. If two root canals exist they may terminate by a common apical foramen.

(*g*) IDENTIFICATION.—Identification is not always easy from a miscellaneous collection of teeth. If the premolar is small, has very rounded margins to its crown, and if the central coronal sulcus is short, and does not extend to the mesial and distal borders, a second maxillary premolar is indicated. It is practically impossible to determine whether it has been implanted in the right or left maxillary bone.

(*h*) SURGICAL ANATOMY.—Its anatomical relationship with the antrum is most important; antrotomy by the oral route may be performed through the socket. According to Sir John Tomes, it is the victim of caries in about 17 *per cent.* of cases. Black's figures are:

Mesial, 16.1; Distal, 17; Labial, 4; Lingual, 10.2; Morsal, 6.7. In France, the proportion is said to be 8 *per cent.*

In opening up the pulp chamber the site for election is the centre of the morsal sulcus.

The Permanent Molars.—The word "molar" is derived from *Molaris*, a millstone, a term which, particularly appropriately, expresses its function in the mouth of Man. Molars differ in shape, size, and external configuration and volume from all the other teeth. The largest of all the dental organs of Man, they occupy the posterior portions of the dental arch. There are three in each maxilla, and three cn each side of the mandible, and thus, in typical circumstances, are twelve in number. They are the sixth, seventh, and eighth teeth from the midline, and are called "first," "second," and "third" respectively. Clinically they are designated the "six-year-old" molar, the "twelve-year-old molar," and the "wisdom tooth." Regarding the first named, this nomenclature is far from being correct, and should be abolished. For the "six-year-old" molar may erupt at any age between four and eight years, the "twelve-year-old" tooth from ten to fourteen, while the "wisdom" tooth, or *dens sapientiæ* of the older writers, often appears long before, and long after, the epoch of wisdom has arrived, if ever it does arrive. The third molars sometimes never do erupt, and it would be well for the civilized races of mankind, if it did disappear entirely from their dental category. The reader is, therefore, strongly advised to cultivate the faculty of naming the molars according to their numerical and not according to their popular designations.

These teeth come into the dental arches behind the milk teeth, and have no predecessors, being derived from the extension backwards of the *Zahnleiste*, which has already been concerned in the formation of the forty anterior deciduous and permanent enamel organs.

The First Right Maxillary Permanent Molar.—This tooth is probably of greater value in the human mouth than the canine, which depends on its importance as an æsthetic addition to the face. On account of its large size and its position, about midway between the extremities of the dental arch, its offices are more purely of a mechanical nature than the other teeth.

Black would attribute to the first molar certain special functions, which are of the utmost importance before the shedding of the deciduous teeth, and often prevent distortion of the features.

He writes[4] (page 263): "In the examination of a considerable number of cases it is found that with the effect of disease and the irregularities that occur in the absorption of the roots of the deciduous teeth, and their replacement by the permanent teeth, the support of the jaws is many times almost completely lost, but for the presence of the first molars. They do much more than this. Accompanying the shedding process, there is a rapid growth of the bones of the jaws and face, making for the changes of the features, from the form in the child and the modelling of the features of the adult. Particularly the space from the lower orbital ridge to the crest of the alveolar process, between the teeth is increasing, the depth of the lower jaw from the crest of the alveolar process to its lower border is increasing. Together these are lengthening the face from above downwards. . . . The formation of the first molars (is) not alone in holding the jaws in their proper relative positions, while the occlusion is broken up in the shedding process, but they also, by their movement in harmony with the general growth of the face, carry the jaws further apart, and in this way assist in the formation of the features by lengthening the face."

Around it centres most discussion. Its orthodontical value cannot be overestimated; the loss sustained by the dental arches, superior and inferior, as a consequence of its removal, premature or otherwise, is enormous, and may be compared to the breaking of the sequence of bricks in an archway by the displacement of the "key-stone." Its apparent inability to ward off early attacks of caries in European mouths, and its homological significance, go to render this tooth the most interesting of the teeth of Man. It figures largely in palæontology, and other abstruse sciences, also because unlike the anterior teeth, it with its congeners often remains more firmly implanted in the jaws than the others, and is, on this account, useful in studying the dental characteristics of many skulls of animals and even prehistoric Man. The single-rooted teeth fall out of their sockets in the dried skull, but the triple-rooted teeth are frequently retained.

The anatomy of this tooth may be conveniently considered under

the following headings: (*a*) Its Mean Measurements; (*b*) its Crown; (*c*) Neck; (*d*) Roots; (*e*) Calcification; (*f*) Pulp cavity; (*g*) Identification; and (*h*) its Surgical Anatomy.

(*a*) MEAN MEASUREMENTS.—From the apex of the palatine root to the free margin of the ridge of enamel on the inner border of the crown the length is 22 mm.; of the anterior buccal root and anterior portion of the internal border, 21 mm.; of the posterior buccal root, and the posterior part of the external border, 19 mm. Black's figures are as follow: Average length of crown, 0.30; of root, 0.51; over all, 0.81 inch.

Variations of Mensuration.—From the apex of the anterior buccal root to the coronal edge, 29 mm., and 11 mm. across the crown in a mesio-distal direction for the largest, and 10 mm. by 4.5 mm. for the smallest examined.

(*b*) CROWN.—The Crown is large and conical in shape, the buccal and lingual surfaces rounder than the mesial and distal. There are five surfaces: (I) The *Buccal*, or outer, convex in both directions, roughly measures twice the length of the second premolar. Quadrilateral in outline, and most constant of all molars in its general pattern, it is narrower above than below, that is, the lower angles spread out and become very rounded. Midway between its anterior and posterior borders a groove is formed passing from above downwards, and dividing it into two nearly equal parts, of which the anterior is the more protuberant. This groove begins at a spot 2 or 3 mm. below the necks of the tooth. The lower border possesses two curves, the convexities of which look downwards, the curves themselves representing the outer parts of the two external cusps.

(*ii*) The *Palatine* or inner surface is more irregular in outline than the buccal; it is also more rounded. Like the former, it is narrower at the neck of the tooth than elsewhere, swelling out to its lowest edge in graceful curves. It is convex in both dimensions. Its surface is unequally divided into two parts by a similar groove to that which obtains on the buccal side. In this instance, however, while starting at about a similar spot near the neck, it passes downwards and backwards, and makes the anterior part by far the larger of the two. The curves of this surface are not so clear as are those of the buccal surface.

(*iii*) *Mesially* the crown presents a horizontally-placed rhomboid, which is very slightly convex, and of which the upper and lower borders are nearly parallel. The straightness of the lower border is due to the depression between the antero-internal and the antero-external cusps, and is insignificant. At times a trifling depression is seen on this surface.

(*iv*) *Distally* the quadrilateral character of the anterior surface is well maintained. It is equally flattened and equally oblong in shape. But the lower border is more deeply grooved than on the former side.

FIG. 134

FIG. 135

FIG. 136

FIG. 137

FIG. 138

FIG. 139

FIG. 134.—The maxillary first molar—Mesial aspect. × $\frac{1}{1}$.
FIG. 135.—The same—Buccal aspect.
FIG. 136.—The same—Lingual aspect.
FIG. 137.—The same—Bucco-lingual section.
FIG. 138.—The same—Mesio-distal section.
FIG. 139.—The same—Various horizontal sections: *A*, through the crown; *B*, the neck; *C*, the mid-portion; *D*, the roots; *E*, near the apices of the roots.

(*v*) The *Morsal Surface* is the most interesting of all. Around the morphology and evolution of its cusps has been waged much polemical warfare. Many years of research have been spent in attempting to ascertain and explain the homologies of its cusps, and to substantiate the claims of the varied and various arguments and deductions brought forward by different zoölogists and palæontologists in the matter.

It presents the outlines of a quadrilateral figure with rounded angles, and surmounted—at each angle—by prominent elevations. The

buccal tubercles or cusps are, on the whole, shorter than the others—and this fact enables the anatomist to establish a difference between this, and the second, and third molars. The palatine border of this surface is longer than the same border on the morsal surface of the second or third molar, another point which seems to distinguish this tooth, whilst a third distinguishing feature lies in the fact that the palatine border of the second molar is a great deal more rounded off than the sharper border of the first.

There are four cusps, an antero-internal or inner mesial, an antero-external or outer mesial, a postero-internal or inner distal, and a postero-external or outer distal, the first and last being more or less connected by a highly accentuated, unmistakable, strong, broad, prominent ridge of enamel, the others being separated by deep fossæ.

Of the four cusps the largest is the antero-internal. It is the homologue of the *protocone*. It is joined to the postero-external cusp by a marked oblique enamel ridge, and is found in the anthropoid ape. Occasionally this ridge is traversed by a slight fissure, which thus unites the anterior and posterior fossæ of the crown. The lowest part of this cusp is the most prominent part of the tooth. The antero-external cusp is joined to the former by the oblique ridge already described, which forms the lower border of the outer surface.

The next largest cusp is the antero-external, the smallest the postero-internal, which is separated from the other by a sulcus which passes from within backwards and sharply outwards. The *postero-external* cusp is the homologue of the *metacone*, the *postero-internal* of the *hypocone*, and the *antero-external* of the *paracone*. An extra, a fifth cusp, is often developed over the antero-internal cusp of this tooth.

(*c*) Neck.—The Neck of the first permanent molar is, on horizontal section, rhomboidal in outline, larger on the palatine than on the buccal aspect. It occupies a horizontal plane, the amelo-cemental junction being very indistinct. (*Cf.* the Deciduous Molars.)

(*d*) Roots.—There are three roots, of which one is placed internally, the palatine, and two externally, the anterior and posterior buccal. Of these, the latter is flattened from side to side, the posterior is shorter than the anterior and generally somewhat straighter, and the anterior frequently inclined to be grooved, and become curved in a backward

direction. Seen from the anterior point of view, the latter more closely approaches the outlines of an isosceles triangle than the former, which is altogether a smaller root. The most important of the three, and the most divergent, thereby ensuring great strength to the implantation of this tooth, is the palatine root, which passes inwards towards the palate, from the junction of the bases of the two buccal roots with the cervical region of the tooth. It is much more cylindrical in shape than the others but still is rather flattened from without inwards. It is frequently twisted and its apical region deflected gently.

Occasionally the buccal roots become fused together, and occasionally the buccal and the palatine. All three roots may communicate with the antrum, particularly the palatine.

(*e*) Calcification.—Calcification of this tooth begins before any of the other of the permanent series. This is a very important point. The earliest signs of its development of dentine and enamel of the cusps in Man have been observed about the *eighth* month of *intra-uterine life*. The hard parts are superficially completed by the ninth or tenth year, and the tooth is erupted from the sixth to the sixth year and sixth month (28 *per cent.*).

(*f*) Pulp Cavity.—The general shape of the Pulp Cavity and the root canals can be ascertained from Figs. 137, 138, and 151. The cornua follow closely the shape and positions of the cusps, the whole pulp chamber that of the crowns. At its base there is an infundibulum whence arise the three radicular canals. Their calibres diminish very rapidly to the apical foramina. The buccal canals are exceedingly flattened from side to side, that of the palatine is generally cylindrical.

(*g*) Identification.—Identification is easy. If the palatine root is held between the thumb and index finger of the left hand and the crown is directed upwards, the end of the oblique ridge of enamel which is nearest to the spectator points to the side to which the tooth belongs.

(*h*) Surgical Anatomy.—The general length of the palatine root is half an inch. The anterior buccal is $\frac{3}{8}$ to $\frac{7}{16}$, and the posterior buccal $\frac{3}{8}$ inch. The entrance to the posterior buccal root is frequently obliterated. Externally, tartar is commonly present on the buccal surface of the crown, owing, no doubt, to its proximity to the orifice of Stenson's duct, and beneath the gum margin, enamel nodules are often formed

between the two buccal roots. The pulp chamber is roughly triangular in shape. It should be opened up thoroughly, to expose well the entrance to the canals.

When extracting this tooth, the forceps blades should be made to grasp the circumference of the palatine root internally, and the space between the buccal roots externally. It is very frequently an oblique-rooted tooth, due to the fact that the posterior buccal root lies internally to its normal position. If it possess a crown of which the obliquity is noticeable, it may be surmised that the position and shape and general character of the roots is irregular also. The anterior buccal root is in close connection with the floor of the antrum. It is the earliest permanent tooth to erupt, and is said, in Europe, to be the first to "decay." Hence, special care should be exercised in cleansing it.

FIG. 140

Bucco-lingual section through a maxillary molar *in situ*, to show its osseous relationships. × $\frac{1}{1}$.

In orthodontics, Angle's system of classification is often adopted regarding the occlusion of this tooth with the opposing mandibular first and second molars. Abscess in the hard palate is produced by suppuration occurring in the palatine root, abscess in the *vestibulum oris* from the buccal roots.

The frequency of the occurrence of caries in this tooth appears to differ in different countries.

In Great Britain it is clinically believed that the first permanent molar is the most frequently carious.

Out of 2628 cases of extractions, on account of caries and its consequences noted by Sir John Tomes, the first molars numbered 1090.

Magitot[15] out of 10,000 cases gave the number as 15.4 *per cent.* (the mandibular first permanent molar 18 *per cent.*), while Black has noted in a hundred persons the following: Caries of the mesial surface, 16; distal, 6.2; buccal, 1.2; palatine, 0.1; morsal, 24 (*i. e.*, the fourth position most frequently observed in the maxillary series, the others being mesial surface of the first incisor, 31.6; mesial surface of

the second incisor, 28; distal surface of the first incisor, 26.3, and the morsal surface of the maxillary first molar). According to Mr. J. G. Turner, dental cysts arise in connexion with this tooth more than any other in the proportion of 47 to 100.

The Second Right Maxillary Permanent Molar.—This tooth, the so-called "twelve-year-old" molar, is the last tooth but one in the maxilla, and usually begins to make its way into the dental arch behind the first permanent molar after the canine and second pre-molar are already in place.

(*a*) Mean Measurements.—Extreme length from apex of palatine root to the most prominent part of the antero-internal cusp is 22 mm. Extreme width across the broad mesial surface 11 mm. Black's measurements are: Average length of crown, 0.28; of root, 0.5; length over all, 0.79 inch.

Variations of Mensuration.—Length, 24 mm. to 29 mm.; width, 10 mm. to 12 mm.

(*b*) Crown.—The Crown is smaller, more inclined to be triangular, and more rounded generally than that of the first molar, otherwise its external configuration closely follows it.

Of the (*i*) *Mesial* and (*ii*) *Distal* surfaces, both more convex and not so flattened as in the first molar, the former is somewhat broader than the latter, and shelves off, on the internal side, to form the prominence of the antero-internal cusp, of which the free extremity is the lowest part of the crown. The *Distal* is more convex than the mesial surface, and rounder, its lower border of equal size, that is, the extremities of the cusps are about the same length.

(*iii*) The *Buccal* surface is like that of the first molar, but shelves off towards the distal part, and the grooving is not extensive, but marked at the lower border.

(*iv*) The *Palatine* surface is exceedingly convex, slopes up to the extremity of the antero-internal cusp, and the groove seen on the corresponding surface of the first molar is here suppressed. The distal portion of this surface may be much diminished in size. In many specimens, this fourth cusp (the postero-internal) is diminutive or even wanting.

(*v*) *Morsal Surface.*—The largest cusp is the antero-internal joined to the postero-external by an oblique ridge which is traversed by a slight sulcus. There are two deep fossæ present, one—anterior—is situated behind the oblique ridge, and the antero-external cusp, and divides into a fissure running between the two external cusps, and another running between the two anterior cusps; and the other—posterior—lying behind the middle part of the oblique ridge, and sending a prolongation or fissure inwards and forwards to divide the postero- and antero-internal cusps from each other.

FIG. 141

FIG. 142

FIG. 143

FIG. 144

FIG. 145

FIG. 146

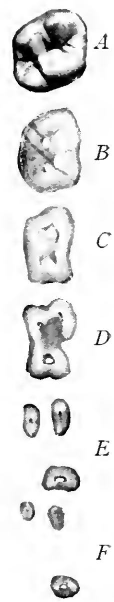


FIG. 141.—The maxillary second molar—Mesial aspect. × $\frac{1}{1}$.
FIG. 142.—The same—Distal aspect.
FIG. 143.—The same—Buccal aspect.
FIG. 144.—The same—Bucco-lingual section.
FIG. 145.—The same—Mesio-distal section.
FIG. 146.—The same—Various horizontal sections: *A*, through the crown; *B*, the neck; *C*, the neck; *D*, mid-portion; *E*, the roots; *F*, the apices.

(*c*) NECK.—The Neck is irregular in outline and circumference, and is simply marked by an annular depression.

(*d*) ROOTS.—The Roots are three in number, are not so divergent as in the first molar, and are generally curved in a distal direction. Sometimes there is fusion of all the roots, with grooves indicating their probable outlines. Often the palatine and anterior buccal roots are confluent, rarely the palatine and the posterior buccal.

(*e*) Calcification.—Calcification begins about the fifth year, and is completed from the sixteenth to the eighteenth year. The tooth begins to erupt about the eleventh year and ninth month.

(*f*) Pulp Cavity and Root Canals. — In shape the former is oblong from the buccal to the palatine side, the cornua are not so very marked, and the floor of the cavity is rounded, or almost flat. With regard to the latter, the canals are shorter and very much more flattened laterally than those possessed by the first molar.

(*g*) Identification.—Identification of this tooth is not difficult, the salient features being the rounded character of the edge of the crown over the palatine root. If the palatine root is held by the thumb and index finger of the left hand, and the crown of the tooth is uppermost, the end of the oblique ridge nearest the spectator points to the side to which it belongs.

(*h*) Surgical Anatomy.—As the external alveolar plate is here very thin, in the operation of extraction, traction on the tooth should be directed outwards towards the cheek. In the performance of alveolar antrotomy for *empyœmi antri* it is often convenient and expedient that the trochar be made to penetrate the upper extremity of the socket of the palatine root.

The Third Right Maxillary Permanent Molar.—This tooth is the most variable in size, shape, position, and character of crown and roots of any of the other molars. It possesses a great variety in the morphology of the crown, two specimens scarcely ever being identical. While the second molar somewhat resembles the first, the third bears only a superficial likeness to the second. It is the smallest of the three, and is often tri-cuspidate.

(*a*) Mean Measurements.—Extreme length from the apex of the anterior buccal root to the most prominent part of the interno-external cusp is 20 mm.; extreme width of mesial surface, 11 mm. Black's figures: Average length of crown, 0.24; of root, 0.44; length over all, 0.65 inch.

Variations of Mensuration.—The smallest examined was 10 mm. long and 4.5 broad in the same situations.

(*b*) Crown.—(*i*) The *Mesial* surface is very flat and broad, there is no cervical prominence or limit, the whole front surface sloping gradually upward from the lower border to the roots.

(*ii*) The *Distal* surface is extremely rounded, convex, and short. The amelo-cemental junction is inconspicuous, but occasionally somewhat grooved. If a fourth cusp is present the highest part of the tooth is the buccal side of the lower border of the distal surface. If three cusps are present, the internal cusp is the highest. All the angles are very rounded.

(*iii*) The *Buccal* surface is identical with that of the first and second molars, but generally shorter and rather more convex. A slight vertical groove may exist on the lower border.

Fig. 147

Fig. 148

Fig. 149

Fig. 150

Fig. 147.—The maxillary third molar—Mesial aspect. $\times \frac{1}{1}$.
Fig. 148.—The same—Distal aspect.
Fig. 149.—The same—Buccal aspect.
Fig. 150.—The same — Mesio-distal section.

(*iv*) The *Palatine* surface is very narrow antero-posteriorly, very convex, and not grooved. Its highest part corresponds to the antero-internal cusp of the first or second molar.

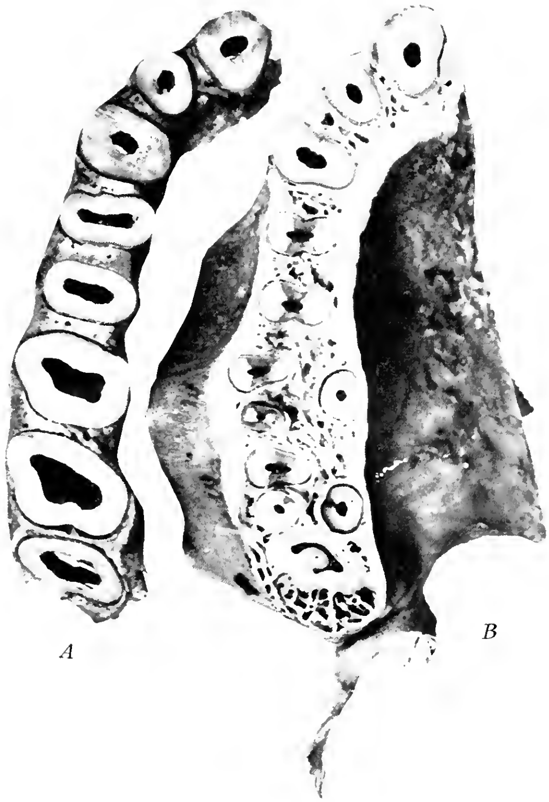
(*v*) The *Morsal* surface: Of the cusps, the postero-internal is the smallest, and in many—perhaps most—instances is entirely suppressed. Probably 50 *per cent.* of these teeth have no fourth cusp. The internal cusp is very large in the tri-cuspidate teeth, and a deep fossa is formed in the middle of the crown and extends outwards as a fissure, between the two external cusps, often sending a smaller fissure backwards to separate the postero-external from the large palatine cusp. The oblique ridge, therefore, is absent in these tri-cuspidate teeth, and now serves to constitute the distal ridge running along the lower border from without inwards.

(*c*) Neck.—The Neck is oblong from without inwards. Its markings are absent in front, but are more or less visible behind.

(*d*) Roots.—The maxillary third molar possesses three roots, two buccal and one palatine, like the first and second molars. Many have

their roots all convergent, some develop four, five, or six roots. In these instances the neck is very much compressed from side to side, and the crown most irregular in outline, shape, and size. The roots are smaller and slenderer than those of the second molar, the palatine being at times even the smallest of the three. When three cusps only exist, the outer two are frequently confluent.

FIG 151



Horizontal sections through the alveolar process of the right maxilla of an adult with the permanent teeth *in situ*. $\times \frac{6}{5}$. *A*, at the gingival margin of the bone; *B*, at the root portions of the teeth. The shapes, sizes, and positions of the pulp cavities and root canals are by no means constant.

(*e*) CALCIFICATION.—Calcification begins about the ninth year, is superficially completed from the eighteenth to the twentieth year and the tooth may erupt from the seventeenth to the twentieth year. It, however, is often not erupted till middle age.

(*f*) Pulp Cavity and Root Canals.—The outlines of the Pulp Cavity and Root Canals are very varied and difficult to describe. The pulp chamber is usually triangular, the outer side being the shortest of the three. The cornua are not pronounced. The orifices of the root canals are closer together than obtains elsewhere, and are very small. If the tooth has a single root, one pulp chamber only may exist, the floor of the pulp cavity which is seen in the other molars being absent.

(*g*) Identification.—Identification can be mainly effected by the size, and slenderness of the roots, and the elimination of the characters of the other molars. If three cusped, then the tooth is the maxillary third molar. If the palatine root is well formed, and is held as described in a previous page, the flattened mesial surface of the crown points to the side to which the tooth belongs.

(*h*) Surgical Anatomy.—The full formation of the apical region of this tooth occurs about the time of eruption, a point worthy of notice when extirpation of the pulp, and filling of the root canals are required. It is frequently impacted and misplaced. (See Fig. 201.)

THE MANDIBULAR SERIES

The Incisors.—The main differences between the maxillary and mandibular incisors lies in the size. Comparison of specimens of each, reveals the fact that the architecture of the latter, although founded on general similar lines is more refined and graceful than the former. The teeth taper most gradually from the incisive edge to the radicular apex. The two first incisors maxillary and mandibular—are the most dissimilar; the two second more closely match each other. Another salient point is that the cingulum, which is often enlarged and overdeveloped in the upper teeth, is usually wholly wanting in the lower; the appearance of a lingual cusp being probably entirely unknown in this situation.

The First Right Mandibular Permanent Incisor.—The smallest tooth of all, it is placed in the front of the mandible immediately to the right of the central line, the mandibular "incisive spot." It bears

the same relationship with regard to its mesial surface to the vertical line passing through the middle of the face (that in the same direction as the sagittal suture of the skull) as does the maxillary first incisor.

(*a*) Mean Measurements.—The extreme length from the apex to the cutting edge is 23 mm., the width at the neck being 6 mm. It is slightly longer in the mesial than on the distal side. Black's figures are as follow: Length of crown, 0.34; of root, 0.47; over all, 0.81 inch.

Variations of Measurement.—The greatest measures, 27.5 mm. long, and 5.5 across the incisive edge; the shortest 18 mm., and 3 mm. in the same diameters.

(*b*) Crown.—The Crown is cone-shaped, the cone having its base compressed from side to side, and the apex (the cutting edge) flattened, and extended from before backwards. It is very small, and presents fewer irregularities of surface and conformation than the corresponding upper tooth. It is, therefore, much more constant in shape and general characteristics. The surfaces are labial, lingual, mesial, and distal.

(*i*) *Labial.*—This is triangular, with the blunt apex of the triangle pointing downwards, and the base at the cutting edge. Convex in both directions, its angles are clearly defined and both acute. At times there are faint traces of a double vertical grooving, which is more marked at the edge than lower down.

(*ii*) The *Lingual* surface is concave in both planes, but more pronounced in a mesio-distal direction. The surface here is also triangular, the apex again at the gingival margin, but acuter than that of the opposite surface.

(*iii*) The *Mesial* aspect is very flat, triangular in outline, having its base at the gingival edge, and its acute apex at the cutting edge. The amelo-cemental junction is very indistinct.

(*iv*) The *Distal* surface is also triangular, slightly concave from above downwards, and slightly convex in the labio-lingual direction. It is somewhat shorter, and somewhat smaller than that on the opposite surface. The incisive border is the widest part of the tooth; its angles are acute.

(*c*) NECK.—The Neck is inconspicuous, being intimately blended with the root.

(*d*) ROOT.—The Root is long, narrow from before backwards, and very flattened laterally. Its anterior border is the broader of the two and at the same time a little longer, and also a little more convex. The posterior border is thin and tapers almost to a point at its apex. The mesial aspect is flat from above downwards, slightly convex from side to side, and possesses no groove. The distal aspect is concave in both directions; a shallow groove runs through the greatest part of its length. The apical foramen is indistinguishable.

FIG. 152

FIG. 153

FIG. 154

FIG. 155

FIG. 156

FIG. 157

FIG. 152.—The mandibular first incisor—Labial aspect. × $\frac{1}{1}$.
FIG. 153.—The same—Lingual aspect.
FIG. 154.—The same—Mesial aspect.
FIG. 155.—The same—Mesio-distal section.
FIG. 156.—The same—Labio-lingual section.
FIG. 157.—The same—Various horizontal sections: *A*, through the crown; *B*, through the crown; *C*, mid-portion; *D*, the root; *E*, near the apex.

(*e*) CALCIFICATION.—Calcification begins during the first year *post natum*, and is completed during the tenth year. The tooth is erupted midway between the sixth and seventh years in 30.5 *per cent.* of cases.

(*f*) PULP.—The Pulp cavity follows very uniformly the external configuration of the tooth. It is flattened in a labio-lingual direction, and its cornua correspond with the angles of its cutting edge. It is naturally exceedingly small and tube-like in the radicular region, and at times may even be bifurcated, and possess two small flattened canals, which, however, become united at the apex.

(*g*) IDENTIFICATION.—If the tooth is placed in a horizontal position with the apex of the root towards the observer the longest side (*i. e.*, from angle to apex) is on the side to which the tooth belongs.

(*h*) Surgical Anatomy.—Usually age changes, such as translucency of the root, occur more frequently at an earlier period in this than in the second incisor. Hence, of all the incisors of the lower jaw, it is the first to be shed. Another common age change is that of the pigmentation, in a mesio-distal direction, of the cutting edge of this and the neighbouring tooth. It may be ascribed to degeneration and discolouration of the pulp which have stained the overlying dentine.

The Second Right Mandibular Permanent Incisor.—This bears a strong superficial resemblance to that just described. It is, however, larger, has a broader crown, is wider at the cutting edge, and has a longer root.

(*a*) Mean Measurements.—Extreme length, 24.5 mm.; width at cutting edge, 6 mm. Black's measurements: Average length of crown, 0.35; front, 0.50; over all, 0.85 inch.

Variations of Mensuration.—The length of the largest was 27 mm.; width, 5.5 at the incisive edge. The smallest was 17 mm. long and 5.5 wide.

(*b*) Crown.—The Crown is more fan-shaped than the first incisor. It has four surfaces.

(*i*) The *Labial* side is triangular, with a blunt apex directed downwards, being slightly convex in both directions. There may be vestiges of a vertical groove in the centre of this surface. The upper border is longer than that of the first incisor.

(*ii*) *Lingually* the crown is very concave from side to side, and slightly so from above downwards, terminating at the neck, in a small prominence, which reminds the student of an attempt at an elevation of the edges of the cingulum. No pits or fissures are ever seen here.

(*iii*) The *Mesial* surface is triangular, having its base below. It is slightly concave. Its junction with the neck of the tooth is indistinguishable.

(*iv*) The *Distal* triangular surface is also concave in both directions.

(*c*) Neck.—The Neck is inconspicuous on the mesial and distal surfaces, slightly visible on the labial, but more marked on the lingual side.

(*d*) Root.—The Root is similar to that of the first incisor, but both labial and lingual aspects are more inclined to be of equal width.

The apex is acute. It is more grooved distally than mesially. Attempts at the formation of two roots often occurs.

(*e*) Calcification.—Calcification begins the first year after birth, and is superficially completed from the tenth to the eleventh. The tooth begins to erupt in 28.5 *per cent.* of cases, about the seventh year and sixth month.

Fig. 158

Fig. 159

Fig. 160

Fig. 161

Fig. 162

Fig. 163

Fig. 164

Fig. 158.—The mandibular second incisor—Labial aspect. $\times \frac{1}{1}$.
Fig. 159.—The same—Lingual aspect.
Fig. 160.—The same—Mesial aspect.
Fig. 161.—The same—Mesio-distal section.
Fig. 162.—The same—Mesio-distal section in another plane.
Fig. 163.—The same—Labio-lingual section.
Fig. 164.—The same—Various horizontal sections: *A*, through the crown; *B*, the neck; *C*, mid-portion; *D*, the root; *E*, near the apex.

(*f*) Pulp Chamber.—The Pulp chamber and root canal are similar in most particulars to those of the first incisors; the latter is frequently bifurcated.

(*g*) Identification.—Identification may be accomplished by the same means as the first incisor. A large mandibular incisor is probably the second.

(*g*) Surgical Anatomy.—It is seldom necessary to have to open up the pulp chamber of this tooth, on account of its immunity from the attacks of dental caries. A spot on the lingual side of the cutting edge centrally placed is, however, the most suitable to choose. If the tooth has become abraded as an old age change, an opening must be effected through the cutting edge, and the direction must be near the labial side.

The Right Mandibular Permanent Canine.—The mandibular canine differs but little from the upper tooth, the main point being the size

of the crown, which is longer in the former than in the latter. The external (labial) outline of the tooth, moreover, is more gently curved from cusp to apex than the other, being modelled on the shape of an arc of a circle, so that the most prominent part is at the neck.

(*a*) MEAN MEASUREMENTS.—Extreme length, 31 mm.; and width, 12 mm. Black's figures are: Length of crown, 0.40; of root, 0.60; over all, 1 inch.

Variations of Mensuration.—The largest examined was 33.5 long, and 8 mm. broad; the shortest, 22.5 long, and 6 mm. broad.*

(*b*) CROWN.—The Crown is cone-shaped and flattened on all four sides, but more on the labial and the lingual than the others. Looked at from above, the labial convexity slopes off, on account of the larger area occupied by the mesial, rather than the lingual surface, thus presenting the outline of an irregular triangle of which the base is directed towards the midline of the jaw. It has four surfaces.

(*i*) The *Labial* surface is convex in both directions, frequently roughened by the presence of horizontal or vertical rows of shallow pits. The lower border is rounded, its upper pointed border (cutting edge) terminates at an excentric spot which encroaches on the right, so that the cutting edge, running from the extremity of the cusp forwards to the mesial angle, is shorter than that running backwards to the distal angle. A slightly raised ridge of enamel often extends downwards, and this gives to the surface the appearance of two vertical shallow grooves, one in front and the other behind.

(*ii*) More concave from side to side than from above downwards the *Lingual* surface has a vertical ridge of enamel which divides it into two unequal parts, of which the anterior is larger than the posterior.

(*iii*) The *Mesial* surface is much broader than the distal, in shape like a blunt triangle, the base of which, on the level of the gum margin, is encroached upon by the cementum. Its height compared to its

* Rarely, this tooth may become enormously developed and assume the dimensions of the inferior canine of the anthropoid ape. A celebrated historical instance occurred in the case of Geoffroy-la-Grand'Dent, surnamed Geoffroi II, of the House of Lusignan, who, as a puissant noble of Poitou, flourished in the Twelfth Century. He was so-called because, in the mediæval French tongue, as recorded in the "Roman de Melusine," written in 1387, by order of Charles V, "il apporta sur terre, une dent qui lui yssoat hors de la bouche plus d'un ponce."

width is remarkable, as the mesial cutting edge extends some distance on to it. It is very flat, hardly convex.

(*iv*) The *Distal* is not so broad as the former surface; it is more convex, and its upper part is thickened by the prominent termination of the distal part of the cutting edge. It is slightly concave both ways, in its lower part.

(*c*) NECK.—The Neck is more pronounced on the labial and lingual sides than on the other surfaces.

FIG. 165

FIG. 166

FIG. 167

FIG. 168

FIG. 169

FIG. 170

FIG. 165.—The mandibular canine—Labial aspect. × $\frac{1}{1}$.
FIG. 166.—The same—Lingual aspect.
FIG. 167.—The same—Mesial aspect.
FIG. 168.—The same—Mesio-distal section.
FIG. 169.—The same—Labio-lingual section.
FIG. 170.—Various horizontal sections: *A*, through the crown; *B*, the neck; *C*, mid-portion; *D*, the root.

(*d*) ROOT.—The Root is long, strong, and broad at the gingival margin, and tapers gradually to its apex, being inclined slightly towards its distal aspect. The labial is broader than the lingual aspect, and the mesial slightly narrower than the distal. Both are grooved, the latter being the more so.

(*e*) CALCIFICATION.—Calcification extends from the third to the twelfth or thirteenth year of childhood, and the date of eruption like the maxillary canine, probably precedes the superficial completion of its calcification and occurs about the eleventh year and third month.

(*f*) PULP CAVITY AND ROOT CANALS.—The Pulp Cavity and Root Canals resemble those of the maxillary teeth, but they are more flattened from side to side.

(*g*) Identification.—To identify the tooth it is necessary to place it in a horizontal position with the apex of its root towards the observer. The shorter portion of the cutting edge (*i. e.*, that which lies between the cusp and the mesial surface) points to the side to which the tooth belongs.

(*h*) Surgical Anatomy.—In treating the contents of the pulp cavity, an opening should be made half-way down the lingual surface.

The First Right Mandibular Premolar.—The architectural features of this tooth are very extraordinary, exhibiting as far as its coronal portion is concerned gradational changes from the canine to the second premolar. It is, of course, a premolar, the homologue of the corresponding tooth in the maxillary bone, but it is not bicuspidate, as it possesses but one prominent cusp. The elevation of the internal cingulum produces a small tubercle, which can, however, in no sense be termed a cusp. It is an interesting tooth from a morphological point of view.

(*a*) Mean Measurements.—Extreme length from summit of cusp to apex, 25 mm.; width across the greatest diameter (mesio-distal) of the crown, 7 mm. Black's figures: Length of crown, 0.30; of root, 0.54; over all, 0.84 inch.

Variations of Mensuration.—The largest examined was 28 mm. long, and 8 mm. wide; and the smallest, 18 mm. long, and 8 mm. wide.

(*b*) Crown.—There are five surfaces to the crown—labial, lingual, mesial, distal, and morsal.

(*i*) The *Labial* surfaces resemble in outline a pentagonal figure, of which the base, at the gingival margin, is straight, the anterior border passing upwards and forwards to join the superior mesial border at the mesial angle, the posterior, passing upwards and backwards to join the superior distal border at the distal angle, both terminating at the extremity of the cusp in approximately the central axis of the tooth. It is slightly convex from before backwards, and exceedingly so from above downwards, giving one the impression that the crown had been bent inwards towards the tongue. Occasionally it exhibits horizontal bands of pits. Its greatest width is between its two superior angles.

(*ii*) Convex, very small and ill-developed is the *Lingual* surface. It presents mainly a conspicuous tubercle probably formed by the elevation of the cingulum.

(*iii*) The *Mesial* surface is quadrangular, its inner part being largely encroached upon by the very convex labial surface.

(*iv*) The *Distal* is more concave than the last surface, terminating at the upper part by a prominent enlargement of the mesial angle.

FIG. 171

FIG 172

FIG. 173

FIG. 174

FIG. 175

FIG. 176

FIG. 171.—The mandibular first premolar—Labial aspect. $\times \frac{1}{1}$.
FIG. 172.—The same—Lingual aspect.
FIG. 173.—The same—Distal aspect.
FIG. 174.—The same—Mesio-distal section.
FIG. 175.—The same—Labio-lingual section.
FIG. 176.—Various horizontal sections: *A*, through the crown; *B*, the neck; *C*, mid-portion; *D*, the root; *E*, near the apex.

(*v*) When viewed from above the *Morsal* surface is roughly triangular in shape, with its base outwards and its apex on the tongue side. The prominent cusp occupies nearly the centre of the longitudinal axis of the tooth, and is the highest portion of the crown. From it there run three ridges of enamel: one anteriorly, forming the upper mesial border of the labial surface, another posteriorly, forming the upper distal border of the labial surface, and a third (the median ridge) running inwards, to divide the crown into two unequal parts, each of which is excavated to form a deep pit, *viz.*, the mesial and distal pits. Its edges are all rounded and well-marked. At times, the median ridge is traversed by a deep fissure which thus unites the mesial and distal pits.

(*c*) NECK.—The Neck is inconspicuous and lies in a horizontal plane.

(*d*) Root.—The Root is, as a rule, straight, the labial aspect broader than the opposite, and the mesial than the distal. The two former are slightly convex; the two latter slightly concave and sometimes grooved. This tooth is often bi-rooted, very rarely triply rooted, the labial, in the latter case, being bifurcated. The apex is frequently deflected backwards.

(*e*) Calcification.—Calcification begins about the fourth year, is superficially completed from the eleventh to twelfth, and the tooth is erupted just before the tenth.

(*f*) Pulp Cavity and Root Canals.—The Pulp Cavity and Root Canals follow the shape of the tooth. A cornu may elongate itself in the direction of the lingual tubercle. The canal is almost cylindrical, and bifurcations may be encountered in practice.

(*g*) Identification.—If the tooth is held with its crown uppermost, and the convex "bent," labial surface, which forms such a striking feature, nearest the observer the rounder portion of the crown carrying the mesial pit is placed on the side to which the tooth belongs.

(*h*) Surgical Anatomy.—Entrance into the pulp cavity may be effected through the ridge nearest the lingual tubercle.

The Second Right Mandibular Premolar.—It is often difficult to distinguish this from its homologue in the maxilla. It is, however, a larger tooth with a quadrangular crown, of which the upper superficies is smaller than that at the neck. This tooth, like its congener, possesses one prominent cusp and several tubercles, the latter being raised portions of the internal aspect of the cingulum. The root is large, and its cusp very rounded. ?

(*a*) Mean Measurements.—Extreme length, 23 mm.; the labio-lingual coronal width being 8 mm. Black's figures: Length of crown, 0.31; of root, 0.56; over all, 0.87 inch.

Variations of Mensuration.—Length, 20 to 25 mm.; width, 7.5 to 8.5 mm.

(*b*) Coronal Surface.—(*i*) The *Labial* surface is larger, and the mesial and distal angles are more accentuated than the last. The extreme apex of the cusp is also more rounded; but it is not "bent" inwards so much, nor is it so sharply convex.

(*ii*) The *Lingual* surface is well defined. In shape it is a flattened rectangular figure, with nearly straight sides, its width being greater than its height. The upper border betrays a slight elevation of the cusps.

(*iii*) and (*iv*) The *Mesial* and *Distal* surfaces are very convex, and about equal in diameter and convexity. Of the two, the upper border of the former is the sharper.

FIG. 177

FIG. 178

FIG. 179

FIG. 180

FIG 181

FIG. 182

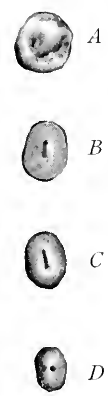


FIG. 177.—The mandibular second premolar—Buccal aspect. $\times \frac{1}{1}$.
FIG. 178.—The same—Lingual aspect.
FIG. 179.—The same—Mesial aspect.
FIG. 180.—The same—Mesio-distal section.
FIG. 181.—The same—Bucco-lingual section.
FIG. 182.—The same—Various horizontal sections: *A*, through the crown; *B*, the neck; *C*, the root; *D*, near the apex.

(*v*) The *Morsal* surface is quadrangular and possesses four borders—labial, lingual, mesial, and distal; all being rounded, and nearly equally elevated. A blunt ridge of enamel extends from the summit of the cusp inwards, a short distance, and is traversed by a deep sulcus, terminating in shallow mesial and distal pits. The internal border is well raised and very rounded, the mesial and distal being less rounded. The length of the fissure between the pits is short—a feature in which this tooth simulates its maxillary homologue.

(*c*) NECK.—The Neck lies in a horizontal plane.

(*d*) ROOT.—The Root is very much longer and larger than that of the first premolar. Here, as in that tooth, the labial aspect is broader than the opposite. The mesial and distal aspects have similar dimensions. It is, as a rule, single, but may be bifid and even trifid.

(*e*) CALCIFICATION.—Calcification begins between the fourth and fifth year, and is superficially completed between the eleventh and

twelfth. The tooth erupts before its completion of calcification, *viz.*, at about ten and one-half years.

(*f*) Pulp Cavity and Root Canal.—The *Pulp Cavity* is noted for the presence of two cornua, one in the labial and the other in the lingual region, the latter being less pronounced than the former. The radicular canal is single, and much flattened from side to side.

(*g*) Identification.—This is extremely difficult. Out of a miscellaneous collection it is practically impossible to determine, with certainty, to which side of the mandible a given tooth belongs.

(*h*) Surgical Anatomy.—The pulp cavity is best reached by drilling through the ridge near the fissure in the middle. Supernumerary ?, Sup premolars on each side of the mandible existed in a negro, the cast of whose mouth is to be seen in the Museum of the Royal Dental Hospital of London, the extra tooth being placed *behind* the other premolar.

The First Right Mandibular Permanent Molar.—This tooth, the homologue of the first maxillary molar, is the second largest of all the teeth. The sixth from the midline of the jaw, it, with its congener, shares the possession of the greatest number of arguments regarding the evolution of its cusps, and its importance or otherwise in orthodontics. By most writers it is believed to be the most frequently carious of all teeth. Thus, Sir John Tomes, from a series of *extracted* specimens, believed it to be the most carious (with the maxillary teeth) in 42 *per cent.*, Magitot, 18 *per cent.*, and Black, 45 *per cent.* of cases as seen in private practice, and *not* extracted specimens. It has two roots.

(*a*) Mean Measurements.—Extreme length from the apex to the external cusp, 21 mm.; across the widest part of the coronal surface, 12 mm. Black's figures: Average length of crown, 0.30; of root, 0.52; over all, 0.82 inch.

Variations of Mensuration.—The largest examined measured 28 mm. by 13 mm., and the smallest, 17 mm. by 7 mm., in the same planes.

(*b*) Crowns.—There are five surfaces for examination.

(*i*) *Mesial:* This is roughly triangular, with its apex considerably reduced and base corresponding with the neck. Convex in both

directions, it is more greatly flattened than the opposite surface. Its upper border is furnished with two acute cusps, which are part and parcel of the two anterior cusps.

(*ii*) *Distally*, the crown partakes very much of the same external characteristics as the former. Three acute points may, however, be observed here, the extra one being that of the fifth cusp, which is placed on a somewhat lower level than the other two. It is exceedingly convex in both directions, and the line of demarcation between its lower border and that of the root is practically indistinguishable.

FIG. 183

FIG. 184

FIG. 185

FIG. 186

FIG. 187

FIG. 188

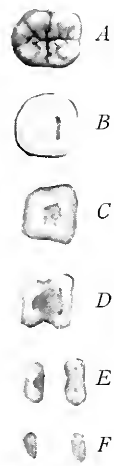


FIG. 183.—The mandibular first molar—Buccal aspect. × 1/1.
FIG. 184.—The same—Lingual aspect.
FIG. 185.—The same—Mesial aspect.
FIG. 186.—The same—Mesio-distal section.
FIG. 187.—The same—Bucco-lingual section.
FIG. 188.—The same—Various horizontal sections: *A*, through the crown; *B*, lower part of crown; *C*, the neck; *D*, the neck; *E*, the roots; *F*, the apices.

(*iii*) The *Buccal* surface has the largest superficies of any of the vertical surfaces, and measures (in the specimens examined) about 12 mm. as compared with 9 mm. on the lingual side. It is convex from above downwards; and also from side to side, and again appears, as in the two premolars, as if it had been "bent" inwards, the shelving being very marked in some instances. Three rounded points give the upper margin an almost serrated outline. Unequal in size, the largest is the anterior, the smallest the posterior. A pit, often, but by no means constantly, is formed on the convex surface just between the two anterior points, at a spot intermediate between the upper and lower borders. The amelo-cemental junction is here clearly discernible.

(*iv*) The *Lingual* surface is quadrangular and its upper border exhibits two acute points, the summits of the anterior and posterior cusps. It is less convex than the former.

(*v*) Roughly trapezoidal in outline, the *Morsal* surface presents five cusps and five fissures for inspection. The former occupy the four corners of the figure, and placed between the two distal, there is a fifth small cusp. They are called the antero-external and internal, the postero-external and internal, and the distal cusps. Of these, the antero-external is the largest, the distal the smallest in typical specimens. The antero-external corresponds to the *protoconid* of the primitive triangle, the antero-internal to the *metaconid*, the postero-external to the *hypoconid*, the postero-internal to the *entoconid*, and the distal to the *hypoconulid*. There is no paraconid present in the mandibular molars of Man, according to Cope and Osborn. The fissures are (*a*) *mesial* running directly forwards; the (*b*) *mesio-buccal* between the anterior and posterior external cusps running directly outwards; the (*c*) *disto-buccal* between the postero-external and distal cusps running backwards; the (*d*) *distal* between the distal and postero-internal cusps running backwards and inwards, and the (*e*) *lingual* between the two internal cusps running inwards.

(*c*) Neck.—The Neck is hardly visible, and lies on a horizontal plane. It is more or less quadrangular.

(*d*) Roots.—The Roots are two in number. The anterior or *mesial* leaves the neck at first in a vertical direction, but soon has a strong declension backwards towards the other root. It is the larger of the two, very broad in the bucco-lingual direction. It has a slight groove on its mesial aspect, and a deeply excavated groove on its distal aspect. Its buccal aspect is wider than the other. The *distal* root, smaller than the last, inclines slightly backwards towards the socket of the second molar. A groove exists on its mesial, but not on its distal aspect. Both borders are of the same size.

(*e*) Calcification.—Calcification begins during the eighth month of intra-uterine life, and is superficially completed by the ninth to the tenth year. It erupts midway between the sixth and seventh year in 30 *per cent.* of cases.

(*f*) Pulp Cavity and Root Canals.—The Pulp Cavity is roughly quadrilateral, having cornua which project somewhat into the four main cusps. There are three root canals, one in the distal and two in the mesial root, all very flattened laterally.

(*g*) Identification.—Identification can be accomplished by holding the crown uppermost, with the fifth intermediate cusp away from the observer. The pit on the buccal surface (if present) is on the *opposite* side to which the tooth belongs. If absent, the rounded character of the same surface indicates the same position the tooth occupies in the jaw.

(*h*) Surgical Anatomy.—The same remarks made about the opposing tooth in the upper jaw apply here. It is important to retain this tooth to preserve the symmetry of the dental arches.

The Second Right Mandibular Permanent Molar.—This tooth is more regular in outline than the one just described. It is somewhat smaller in build, rounder, and has no fifth cusp. Its roots are more confluent.

(*a*) Mean Measurements.—Extreme length, 23 mm. from the apex of the mesial root to the crest of the antero-internal cusp, and 11 mm. across the widest part of the crown, *viz.*, the buccal surface. Black's figures: Average length of crown, 0.27; of root, 0.50; over all, 0.78 inch.

Variations of Mensuration.—Length, 21 mm. to 24 mm.; width, 10.5 to 11.5 mm.

(*b*) Crown.—The Crown is quadrilateral, rounded, and symmetrical.

(*i*) The *Mesial* surface is similar in every way to the corresponding surface of the first molar, except that the external border has a more curved slope.

(*ii*) The *Distal* surface is like that of the first molar, except that it is much more convex and rounded. Its junction with the tooth is more highly differentiated.

(*iii*) The *Buccal* surface resembles the last named, being square in general outline and considerably rounded. There is a tendency for the buccal fissure to descend some short distance on this surface.

(*iv*) The *Lingual* is less extensive in area than the last surface; its upper border has a deep notch in the centre, dividing the summits of the two cusps. It is flatter than the buccal.

(*v*) The *Morsal* surface presents four cusps and four fissures for description, two anterior and two posterior, named respectively, from their situation, antero-external and internal, and postero-external and internal. The antero-external cusp represents the homologue of the *protoconid*, the antero-internal of the *metaconid*, the postero-external of the *hypoconid*, and the postero-internal of the *entoconid*. All cusps are nearly equal in size, and share the same structural characteristics. The outer two have rounded, the inner two, acute extremities. The fissures are deep, and run straight outwards, forwards, inwards, and backwards.

FIG. 189

FIG. 190

FIG. 191

FIG. 192

FIG. 193

FIG. 194

FIG. 189.—The mandibular second molar—Buccal aspect. $\times \frac{1}{1}$.
FIG. 190.—The same—Lingual aspect.
FIG. 191.—The same—Mesial aspect.
FIG. 192.—The same—Mesio-distal section.
FIG. 193.—The same—Bucco-lingual section.
FIG. 194.—The same—Various horizontal sections: *A*, through the crown; *B*, through the crown; *C*, the neck; *D*, mid-portion; *E*, the roots; *F*, near the apices.

(*c*) NECK.—The Neck lies in a horizontal plane, and is well marked.

(*d*) ROOTS.—Of the Roots, two in number, the *anterior* is again the broader and slightly shorter than its neighbour. It is very greatly deflected backwards and is rather twisted on its own axis. It tapers gradually to its apex, is very flattened from side to side, and grooved on both aspects, that on the distal side being very pronounced. The *distal* root is straight, narrow, and long. It too has a backward

declension, and is grooved on its mesial aspect. The distal aspect is rounded and slightly concave from above downwards.

(*e*) CALCIFICATION.—Calcification begins about the fifth year *post natum*, and is superficially completed by the sixteenth or seventeenth year. The tooth is erupted close to the twelfth year.

(*f*) IDENTIFICATION.—The possession of a square crown and two roots distinguishes this tooth from any of the other molars. Held crown uppermost, with the larger root nearest the observer, the flat internal lingual surface points to the side to which the tooth belongs.

(*g*) SURGICAL ANATOMY.—Access to the pulp cavity can be best made through the central portion of the morsal surface.

FIG. 195

FIG. 196

FIG. 197

FIG. 198

FIG. 195.—The mandibular third molar—Buccal aspect. $\times \frac{1}{1}$.
FIG. 196.—The same—Mesial aspect.
FIG. 197.—The same—Lingual aspect.
FIG. 198.—The same—Mesio-distal section.

The Third Right Mandibular Permanent Molar.—While the third molars in both jaws are most variable in shape and size of all the teeth, and while the maxillary molar is frequently very small in architecture, it is seldom that the mandibular third molar becomes less voluminous in its size, but *per contra*, it usually is a large tooth, and its variations tend in an enlarged direction. It is frequently entirely suppressed. It makes its appearance less irregularly than the corresponding maxillary tooth. It may have four, or it may have five cusps, or it may have seven or eight diminutive cusps.

(*a*) MEAN MEASUREMENTS.—Its greatest diameters may be 16 mm. and 10 mm. in the coronal region.

Variations of Mensuration.—Length, 14 mm. to 18 mm.; width, 8 mm. to 12 mm.

(*b*) CROWN.—The Crown is difficult to describe. No two are nearly alike. Generally it may be averred that the distal and buccal surfaces are the most convex, the mesial the flattest, and the lingual intermediate with regard to its convexity, in comparison with the others. The

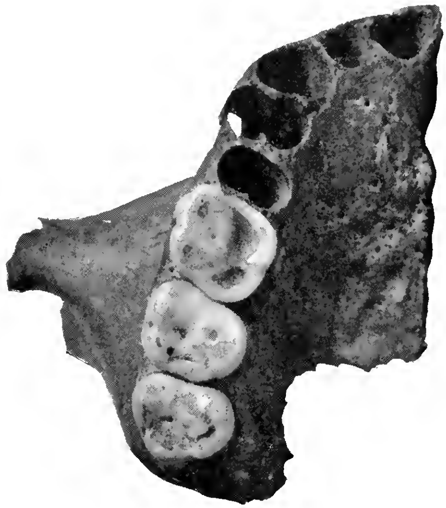
whole crown has rounded angles and surfaces, the cusps are only slightly elevated, the fissures and pits on its morsal surface, shallow.

(*c*) NECK.—The Neck is similar to that of the second molar.

FIG. 199

Horizontal sections through the alveolar process of the right half of the mandible of an adult, with the permanent teeth *in situ*. $\times \frac{6}{5}$. *A*, at the gingival margin of the bone; *B*, at the root portions of the teeth. The shapes, sizes, and positions of the pulp cavities and root canals are by no means constant.

FIG. 200



Palatal aspect of right maxilla of man showing age changes of crowns of the permanent molars, the first being the most, and the third, the least affected. $\times \frac{11}{10}$.

FIG. 201

Radiograph of the left maxilla of a woman, showing an impacted mal-placed maxillary third molar.

(*d*) ROOTS.—The Roots are generally short and taper rapidly to their extremities. They are often confluent. There may be two in number, the most normal type—there may be dichotomy of one or two, or bi-dichotomy even may take place, giving this tooth four or even five roots. The general direction of the roots is backwards.

(*e*) CALCIFICATION.—Calcification begins between the eighth and ninth years, and is superficially completed by the eighteenth year. It erupts, probably, on the average about the twentieth year.

(*f*) IDENTIFICATION.—It is almost impossible to determine to which side this tooth belongs. If at all typical, the description of the second mandibular molar applies also to this tooth.

(*g*) PULP CAVITY.—A general description of the shape, size, and variations of this cannot be given owing to its frequent atypical characteristics.

(*h*) SURGICAL ANATOMY.—This tooth varies very considerably in its position. It is commonly everted in an outward direction and is implanted in the ascending ramus of the jaw. Rarely it may be placed near the sigmoid notch. It varies in direction, being frequently tilted forwards. It may erupt in a normal manner—or partially—when the soft tissues may overlap the whole or portion only of the crown—or not at all. It is often impacted, being obstructed by the second molar through lack of room in the jaw. Inflammatory conditions of the circumdental tissues may induce tonsillitis and pharyngitis, dysphagia, and, if suppurative, trismus, due to the infiltration of the inflammatory products. Infection may spread at times from the dental and maxillary veins to the cavernous sinus through the pterygoid plexus.

THE DECIDUOUS TEETH

The architecture copied by the external configuration of the teeth of the milk series is essentially that of the permanent dentition. The main points of difference lie in their proportions, each tooth being conspicuously smaller—especially in the anterior regions of the mouth—than its successor; its crown is shorter, its root shorter, and its neck more constricted, a fact very noticeable in the molar series. The

latter feature, unless abnormal, enables the observer to state at once to which dentition a tooth belongs. The crowns are more rotund in consequence. The deep cervical contraction hitherto believed to be occasioned by an undue prominence and thickening of the termination of the enamel is caused by a curious outward bending of the dentinal tubes.

In colour the deciduous are paler than the permanent teeth.

It is unnecessary to describe at all fully the morphology of the *Incisors*, which follow in a less accentuated fashion the conformation of the permanent teeth. They are very conical and their angles are not so pronounced.

At birth, the straight cutting edge is trilobed, but the tubercles quickly disappear, according to some writers, as a consequence of attrition. They probably afford some clue to the mode of development of the enamel.

The roots of the maxillary teeth are almost entirely conical, those of the lower somewhat flattened on their mesial and distal aspects. The largest of the four are the first maxillary and the second mandibular incisors. Of the maxillary teeth, the distal angle is more obtuse than the other, from an examination of which the side of the mouth to which it belongs can be readily ascertained.

Of the incisors it is difficult to differentiate between the first and second, as in both instances the angles are more or less acute.

The crowns of the *Canines* are usually somewhat conical in shape, having surfaces as in the corresponding permanent teeth. Of these, that on the labial side presents a slight prominence in a vertical direction.

The neck occupies a plane which is more horizontal than in the incisor. It is also more pronounced. It is difficult to discriminate between those implanted in the upper and in the lower jaw, but of the two it is probable that the latter is slightly the smaller. The distal angle is very rounded.

The *Molars* correspond closely to the patterns of the permanent teeth. The crowns, however, are, on the whole, shorter. They are very disproportionate in size, the second being much larger than the first. Each crown has five surfaces: a morsal, buccal, lingual, mesial,

and distal. The former has three, four, or five cusps, separated by sulci of varying depth. The cusps differ in height; in the maxilla, those

Fig. 202 Fig. 203 Fig. 204 Fig. 205




Fig. 202.—The maxillary deciduous first incisor—Labial aspect. $\times \frac{11}{10}$.
Fig. 203.—The mandibular deciduous first incisor—Labial aspect. $\times \frac{11}{10}$.
Fig. 204.—The maxillary deciduous second incisor—Labial aspect. $\times \frac{11}{10}$.
Fig. 205.—The mandibular deciduous second incisor—Labial aspect. $\times \frac{11}{10}$.

Fig. 206 Fig. 207 Fig. 208 Fig. 209 Fig. 210





Fig. 206.—The maxillary deciduous canine—Labial aspect. $\times \frac{1}{1}$.
Fig. 207.—The same—Lingual aspect.
Fig. 208.—The same—Distal aspect.
Fig. 209.—The same — Labio-lingual section.
Fig. 210.—The same — Mesio-distal section.

Fig. 211 Fig. 212 Fig. 213 Fig. 214 Fig. 215





Fig. 211.—The mandibular deciduous canine—Labial aspect. $\times \frac{1}{1}$.
Fig. 212.—The same—Lingual aspect.
Fig. 213.—The same — Mesio-labial aspect.
Fig. 214.—The same — Labio-lingual section.
Fig. 215.—The same — Mesio-distal section.

Fig. 216 Fig. 217 Fig. 218 Fig. 219 Fig. 220





Fig. 216.—The maxillary deciduous first molar—Distal aspect. $\times \frac{1}{1}$.
Fig. 217.—The same—Mesial aspect.
Fig. 218.—The same—Buccal aspect.
Fig. 219.—The same—Bucco-lingual section.
Fig. 220.—The same—Mesio-distal section.

on the lingual side are more elevated than the others; in the mandible the opposite rule obtains. The roots, three in number, of the upper

series are cylindrical, widely divergent in the first, and less in the second.

FIG. 221.—The mandibular deciduous first molar—Buccal aspect. × $\frac{1}{1}$.
FIG. 222.—The same — Lingual aspect.
FIG. 223.—The same — Distal aspect.
FIG. 224.—The same — Mesio-distal section.
FIG. 225.—The same — Bucco-lingual section.

FIG. 221

FIG. 222

FIG. 223

FIG. 224

FIG. 225


FIG. 226.—The maxillary deciduous second molar—Mesial aspect. × $\frac{1}{1}$.
FIG. 227.—The same—Distal aspect.
FIG. 228.—The same—Buccal aspect.
FIG. 229.—The same—Mesio-distal section.
FIG. 230.—The same—Bucco-lingual section.

FIG. 226

FIG. 227

FIG. 228

FIG. 229

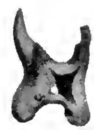
FIG. 230


FIG. 231. — The mandibular deciduous second molar — Lingual aspect. × $\frac{1}{1}$.
FIG. 232.—The same—Buccal aspect.
FIG. 233.—The same—Distal aspect.
FIG. 234.—The same—Mesio-distal section.
FIG. 235.—The same—Bucco-lingual section.

FIG. 231

FIG. 232

FIG. 233

FIG. 234

FIG. 235


The first maxillary molars are somewhat triangular in outline, the lower more flattened on their labio-lingual surfaces. The former has three cusps: one on the lingual side, two on the buccal. Occasionally this tooth has the appearance of a small premolar. Of the four cusps of the second molar, the postero-external is joined to the antero-internal by an oblique ridge, which, therefore, runs outwards and slightly backwards.

15

The lower second molar possesses five cusps, three placed externally (the most posterior being the smallest), and two on the lingual side. The position of the fifth cusp is a guide to the identification of the tooth.

Size.—The Variations in the size of the deciduous teeth are very small. Just as there is, as a rule, but little deviation from their position in the dental arch, so the measurements of the teeth are fairly constant, much more so than their successors. If large, they are collectively so, not isolated or symmetrical, as for instance, in the first permanent incisors.

The following figures represent the average widths of the crowns of these teeth, on their labial surfaces, taken in millimetres:[10]

e	*d*	*c*	*b*	*a*	*a*	*b*	*c*	*d*	*e*
8·6	6·8	6·6	5·3	6·2	6·5	5·2	6·6	6·8	8·5
9·4	7·8	5·7	4·4	3·8	3·8	4·4	5·6	7·7	9·6

Variations of Mensuration.—First Incisors—5.6 to 7.0; *Second Incisors*—4.2 to 6.0; *Canines*—5.7 to 7.1; *First Molars*—6.0 to 7.5; *Second Molars*—6.7 to 9.0 mm.

Surgical Anatomy.—Caries of these teeth leading to inflammation of the pulp and its subsequent suppuration often leaves its mark behind in structural changes of the enamel of the permanent teeth, such as hypoplasia, and perhaps a certain amount of discolouration.

AGE CHANGES IN THE TEETH

In colour, the blue whiteness of young specimens disappears and gives place to a yellow tinge attrition, the middle portions of the cutting edges of the incisors often become discoloured and brown, and remind one somewhat of the "marks" in the teeth of the horse. This is best observed in the molars, when the cusps have been worn away and a table of varying pattern remains.

The roots become, as age advances, translucent, especially those of the mandibular incisors. Exactly how this is produced is not yet known; it is believed to be due to a calcification of the hard tissues, which causes a closing of the dentinal tubes and an approximation of

the refractive indices of the matrix and the tubules. It is important to note that old age changes in the dentine, cementum, pulp, or periodontal membrane are quite independent of the age of the patient. The teeth of children frequently exhibit senile conditions, the crowns often becoming faceted, and the pulps undergoing fibroid degeneration.

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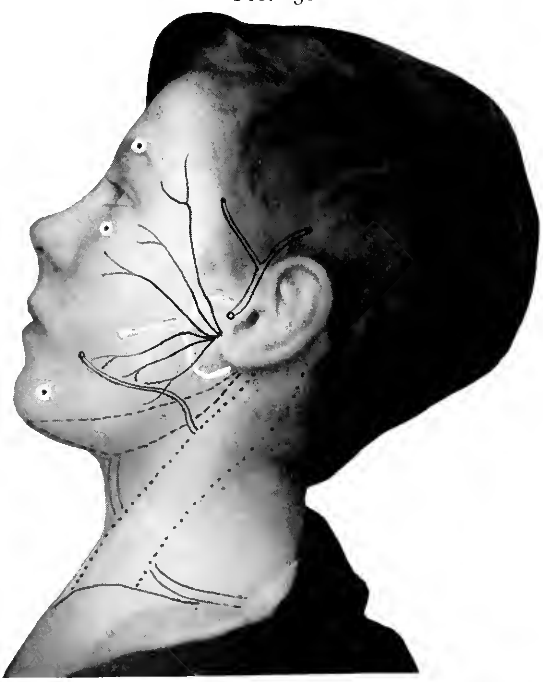
CHAPTER XI

THE RELATIONSHIPS OF THE TEETH OF MAN

The Mutual Association of the Teeth with the Mouth and Osseous System.—The Nervous System.—The Vascular System.—The Lymphatic System.

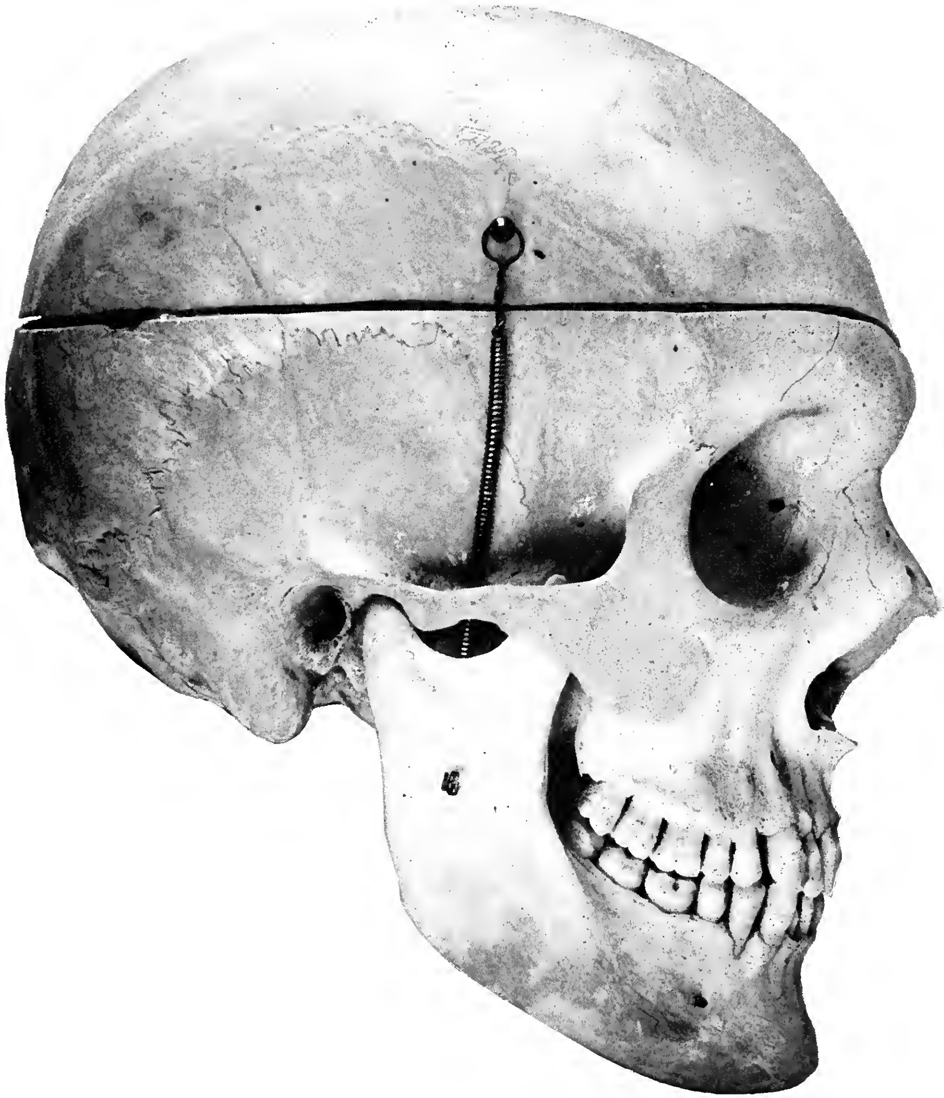
THE importance of and clinical significance attaching to the subject about to be discussed is probably second to no other which has been occupying the attention of the reader. Too frequently the dental

FIG. 236



The surface markings of the superficial structures of the face and neck. The positions of the parotid gland and Stenson's duct are shown in white outline; the points of emergence of the supra-orbital, infra-orbital, and mental nerves in white, with black centres; and, in black, the six branches of the terminations of the facial nerve, the facial artery, and the superficial temporal artery dividing into anterior and posterior branches. The outlines of the sternocleidomastoid muscle, the sub-maxillary triangle, the superior carotid triangle, the inferior carotid triangle, and the subclavian triangle are also indicated. The condyle can be felt immediately in front of the tragus.

PLATE II



A Human Skull in Norma Lateralis. $\times \frac{9}{10}$

surgeon forgets that the teeth are part and parcel of the human economy and treats them as if they were something separate. Here, however, their relationships to the associated parts will be narrated in order to draw attention to their close connexion with other systems of the body and the bearing this topography has upon them.

It will be convenient to describe these observations under the subdivisions of:

A. The Mouth and Osseous System and the Dental Arches.

B. The Nervous System—

(*i*) Anatomical.

(*ii*) Physiological.

C. The Vascular System.

D. The Lymphatic System.

THE MOUTH AND OSSEOUS SYSTEM

The oral cavity has in front a transverse aperture, the *rima oris;* behind, it communicates with the pharynx through the *isthmus faucium.*

FIG. 237

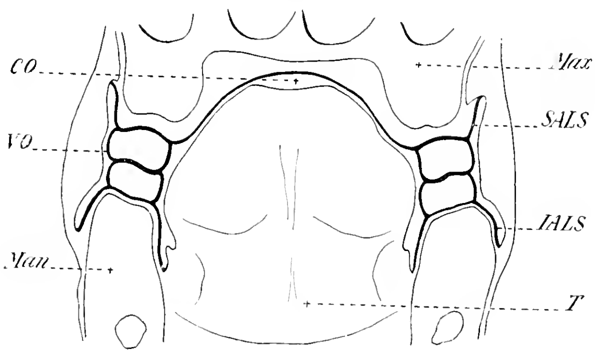


Diagram of coronal section of the mouth behind the second molar tooth. × $\frac{9}{10}$. (After Johnson Symington.) *VO*, *vestibulum oris; CO*, *cavum oris; SALS*, superior alveolo-labial sulcus; *IALS*, inferior alveolo-labial sulcus; *Max*, maxilla; *Man*, mandible; *T*, tongue.

The cavity is divided into two parts: An outer (*vestibulum oris*), bounded externally by the lips and cheeks, and internally by the teeth and gums which cover the outer aspect of the alveolar process of the jaws. The roof and floor are formed by a reflexion of the mucous

membrane of the lips and cheeks inwards to the alveolar processes, which it joins about the level of the middle of the roots of the teeth. The extension upwards and downwards of the vestibule of the mouth forms the *superior* and *inferior alveolo-labial* or *buccal sulci*. A vertical fold of mucous membrane is found in the middle line called the *frænum labii*.

With the mouth closed, the following soft parts externally covering the teeth are observed:

The buccal orifice, separating the upper and lower lips, having at each extremity the buccal commissure, the naso-labial furrow, intervening in the middle line between the upper lip and the base of the nose, and beneath the lower lip in the midline, the labio-mental depression.

Inspection of the mouth considerably open shows in the midline the *frænum labii superioris et inferioris*, the dental arches and gums, the pale mucous membrane of the hard and soft palates, the isthmus of the fauces, the uvula, the anterior pillar of the fauces, and occasionally the tonsils. Occupying the floor of the mouth is the dorsum of the tongue, which if raised, exhibits on its inferior surface in the midline the lingual frænum, the sublingual folds, with the sublingual caruncle (the orifice of the sublingual duct) in close proximity to the *frænum linguæ* and higher up the ranine folds (Fig. 239), and an innermost portion called the *cavum oris*, which lies inside the concavities formed by the dental arches. The *roof* is the hard and soft palate; the floor, the tongue.

The *Parotid Salivary Gland* opens into the former by means of the parotid duct opposite the buccal aspect of the crown of the second maxillary molar, and the *submaxillary* and *sublingual glands* open into the latter. Of these the duct of the submaxillary salivary gland (Wharton's) terminates by a narrow orifice on the summit of the sublingual caruncle, at the side of the *frænum linguæ;* and the ducts of the sublingual salivary gland, of which there may be ten to twenty, end, some by uniting to form a tube (the duct of Bartholin) to open into the Whartonian duct, the others (the ducts of Rivini) to open separately into the mouth through small apertures in the mucous membrane lying over the gland itself.

During the occlusion of the teeth, the *vestibulum oris* and *cavum oris* communicate only through the interdental spaces, and a larger opening placed behind the third molar and in front of the ramus of the jaw (Fig. 237).

The labial mucous glands open on the inner aspect of the lips, being situated between the mucous membrane and the *orbicularis oris* muscle. The buccal glands lie between the mucous membrane of the cheek and the buccinator muscle. The molar glands are found between the masseter and buccinator muscles; they are larger than the others, and the terminations of their short separate ducts are placed in the immediate neighbourhood of the third molar.

FIG. 238

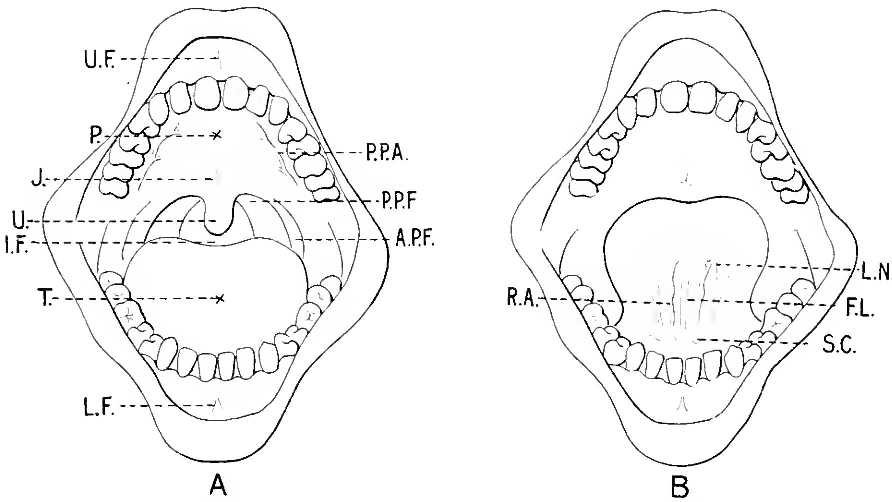


Diagram of the buccal cavity, *A*, with the tongue on the floor of the mouth; and *B*, raised to show its under surface. *U.F.*, frenum of upper lip; *L.F.*, frenum of lower lip; *P.*, vault of the palate; *J.*, junction of the hard and soft palates in the middle line; *U.*, uvula; *P.P.A.*, posterior palatine artery; *I.F.*, isthmus of the fauces; *P.P.F.*, posterior pillar of the fauces; *A.P.F.*, anterior pillar of the fauces; *T.*, tongue; *L.N.*, lingual nerve; *R.A.*, ranine artery; *F.L.*, frænum linguæ; *S.C.*, sublingual caruncle (orifice of Wharton's duct).

The palate consists of the hard and soft palates. In sagittal section it is concave from before backwards and also from side to side. There exist many variations in its shape and size. Broca described four main forms depending on the direction of its walls. Dieulafé and Tournier[2] take note not only of this anatomical factor, but also of the curve of

its summit. In 70 *per cent.* of cases the type presented an arch with a rounded summit and convergent walls, which they designated the (*i*) elliptical form; (*ii*) in 22 *per cent.* of cases there were convergent walls with a flattened roof; (*iii*) in 6 *per cent.* a rectilinear summit with slightly divergent walls, and (*iv*) in 4 *per cent.*, "un type arrondi et à branches divergentes, hyperbolique" (Fig. 239).

FIG. 239

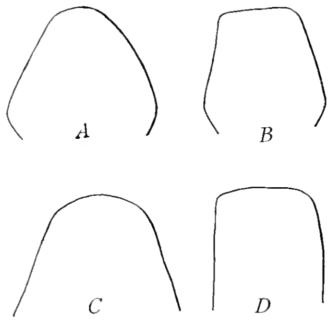


Diagram showing the four main types of shapes of the arch of the palate in man. (After Dieulafé and Tournier.) *A*, the elliptical (70 *per cent.*); *B*, the semi-elliptical (20 *per cent.*); *C*, the divergent (6 *per cent.*); *D*, the hyperbolic (4 *per cent.*).

The palatal rugæ, which are merely thick mucosa, are arranged longitudinally and transversely. In the middle line there is a longitudinal ridge or raphé which ends between the two first incisors in an eminence, the *incisive pad*, "alveolar point," or *papilla palatina*. The papilla corresponds with the anterior palatine fossa, and receives the terminations of the naso-palatine and anterior palatine nerves. On its surface there are sometimes found two small *culs de sac* which represent the orifices of the foramen of Stenson.

Stenson's duct, two and a half inches in length, opens opposite the crown of the second maxillary molar, and *Wharton's duct*, two inches long, close to the side of the *frænum linguæ*.

The antrum of Highmore is a cavity in the superior maxilla which varies very considerably in shape, size, and cubic capacity. Roughly triangular, its apex is placed towards the malar process of the bone, its base to the outer wall of the nose, its walls corresponding to the

orbital, facial, and zygomatic surfaces of the superior maxilla. Crossing its posterior wall are the *posterior dental canals*.

The roots of the first, second, and third maxillary molars very frequently project slightly into it, but at times there may be direct communication between the sockets of both premolars, and even the canine.

The Dental Arches.—Of these the upper is elliptical, the lower, parabolic in outline. The former is rather longer than the latter, so that the maxillary teeth slightly overlap those of the mandible in front and at the sides. There may be several deviations from this rule, as explained and described by Choquet.[1]

There is no diastema in the jaws of Man. But Professor Duckworth (see Chapter IX) considers it not very rare in European skulls, and fairly common in the natives of New Guinea.

The Mutual Relationships of the Permanent Teeth.—The teeth in Man do not, in normal circumstances, occlude by means of their cusps, but by a perfect system of interdigitation. Indeed, Nature has made the shapes of human molar teeth so perfectly, that they cannot do harm to the soft muscular tissues with which they come into contact, and by means of their rounded and bunodont character are efficient masticators; and while they lose their protective cuticle (Nasmyth's membrane), by abrasion, over the summits of these cusps, provides, here, self-cleansing surfaces with regard to the eating of food.

The morsal surfaces of the premolars and molars are not in the same horizontal plane, that of the lower cheek teeth forming a slight curve the concavity of which receives the morsal surfaces of the upper teeth arranged in a gentle convexity, the curve of Graf von Spee. The cutting edges of the mandibular incisors and canines form a rather less marked curve, the convexity of which looks upwards.

There is coincidence of the central lines of the two arches. In occlusion—vulgarly termed articulation—the maxillary first incisors overlap the upper third of the labial surfaces of the two corresponding mandibular teeth. They also, from the disparity in the size of the lower teeth, overlap the whole of the crown of the first and about half of the second incisor in a lateral direction.

The lingual aspect of the maxillary second incisor overlaps the labial surface of the lower corresponding tooth and the canine; the lingual surface, therefore, of the upper first incisor occludes with the upper part of the labial surfaces of the two lower incisors, and the lingual surface of the upper second incisor with the labial surfaces of the mandibular second incisor and canine.

The labial surface of the mandibular canine strikes against the lingual surface of the maxillary canine, which occludes also on its distal portion with the buccal surface of the first mandibular premolar.

FIG. 240

Occlusion of the permanent teeth of an adult man. $\times \frac{9}{10}$.

Other occlusions of the cheek teeth must be briefly described, and are as follows:

(A) The distal portion of the large external cusp of the first mandibular premolar, with the mesial ridges of the buccal and lingual cusps of the upper corresponding teeth.

(B) Both external and internal cusps of the first maxillary premolar in front, and the mesial ridges of the same cusps of the second premolar behind, with the buccal cusp of the second mandibular premolar.

(C) The internal cusp of the maxillary first premolar with the distal ridges of both cusps of the lower first premolar in front, and the mesial ridges of both cusps of the second mandibular premolar behind.

(D) The internal cusp of the second maxillary premolar interdigitates with the posterior ridges of the two cusps of the second mandibular premolar in front, and behind with the antero-external and antero-internal cusps of the first molar.

(E) The antero-external cusp of the first mandibular molar occludes with the distal ridges of both cusps of the second maxillary premolar in front, and the antero-external and antero-internal cusps of the maxillary first molar behind, while the antero-external cusp of the lower first molar occludes with the central portion of the morsal surface of the upper first molar, and the postero-external with the posterior portion of the morsal surface of the same tooth.

(F) The antero-external cusp of the first maxillary molar interdigitates with the central sulcus of the corresponding lower tooth, in front, and the postero-external with the postero-lingual and postero-buccal cusps of the first mandibular molar and the antero-external and antero-internal of the second lower molar.

(G) The antero-external cusp of the second mandibular molar meets the postero-external and postero-internal cusps of the first maxillary molar in front, and the antero-external and antero-internal cusps of the second maxillary molar behind. The postero-internal cusp of the second lower molar coincides with the central part of the crown of the second upper molar.

(H) The antero-external cusp of the second maxillary molar occludes with the central part of the crown of the second mandibular molar, and the postero-external cusp, with both posterior cusps of the second mandibular molar in front, and both the anterior cusps of the third mandibular molar behind.

Variations.—These conditions obtain in normal occlusion of the teeth. It is very obvious, however, that many variations may and do occur. Orthodontics is a branch of dental surgery based upon these irregularities and deviations from the normal and orthodontical science and art aims at their study and correction. Clinically, some of them are

spoken of as "edge to edge bite," "superior protrusion," "open bite," "underhung bite," etc., clumsy definitions which are more forcible than accurate (see Preface).

Fig. 241

Radiograph of the normal jaws of an adult, aged nineteen years. There were no evidences of dental or oral disease, and there was no caries. *Cf.* Fig. 294.

FIG. 242

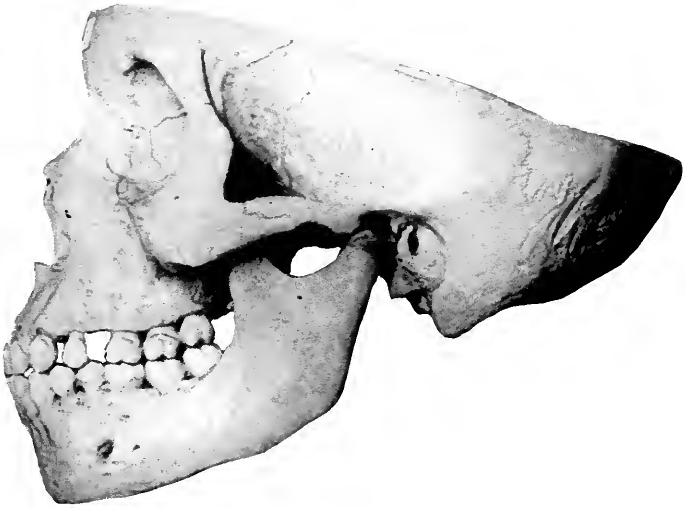
Human skull showing enharmosis. $\times \frac{3}{5}$.

FIG. 243

The same—front aspect.

With a view of placing these atypical modifications on a scientific basis, Grevers,[3] of Utrecht, following up the work of Iszlay, Stenfeld, and L. Meyer, suggests certain terms to signify these anomalies.

FIG. 244



Human skull showing prosharmosis. $\times \frac{3}{5}$.

FIG. 245

The same—front aspect.

FIG. 246

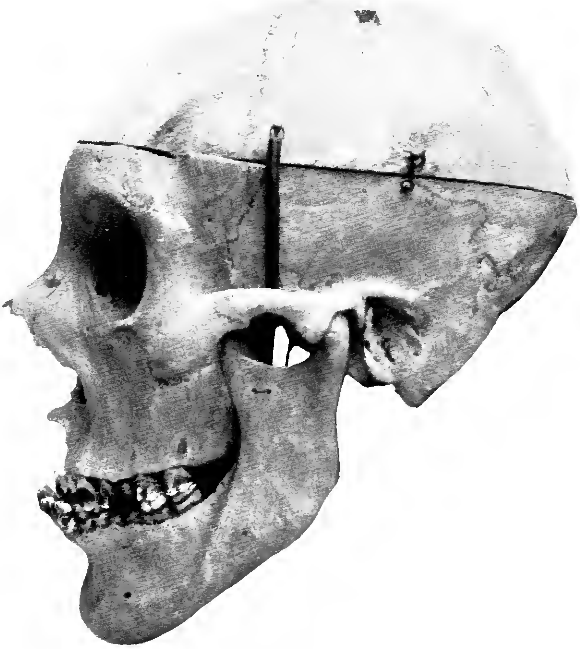
Human skull showing di-enharmosis. $\times \frac{3}{5}$

FIG. 247

The same—front aspect.

Thus the normal position of the teeth in the dental arches and in contact with one another, as already described, is known as *enharmosis*.

FIG. 248



Human skull showing epharmosis. $\times \frac{3}{5}$.

He proposes the use of such terms as

I. *Enharmosis*—a normal bite, maxillary teeth projecting slightly.
II. *Epharmosis*—an "underhung bite," mandibular teeth projecting.
III. *Prosharmosis*—an "edge to edge" bite.
IV. *Opharmosis*—an "open bite."
V. *Disharmosis*—a "cross bite," so-called.
VI. *Tyrpharmosis*—a mixed up, irregular bite which does not come under any of the preceding headings, and may be a mixture of two or more.

Each of these groups can be further differentiated from the others. Thus if the occlusion is quite typical, the condition is called *eu-enharmosis;* if the space between the upper and lower teeth is greater—*di-enharmosis;* and if the upper teeth cover the labial surfaces of the

lower entirely, and the latter actually bite in the mucous membrane of the hard palate, the condition may be called *dys-enharmosis*.

In Group II a reversed state may be sometimes noticed, and using the three affixes already noted, spoken of as *eu-epharmosis*, when the lower teeth touch the *labial* surfaces of the upper and no intervening space exists; *di-epharmosis* the same, but when a great space exists; and *dys-epharmosis* when the lower series cover the upper teeth entirely with little space intervening.

The other groups may be similarly subdivided. By noting these terms the writer would urge the reader to adopt this newer and more scientific nomenclature.

THE NERVOUS SYSTEM

This probably is the most important from a physiological and clinical and pathological point of view.

Anatomical Relationships.—The anatomical relationships may be now briefly described.

UPPER JAW.—In the upper jaw, the superior maxillary, or the second division of the fifth pair of nerves, gives off, in the *spheno-maxillary fossa*,

(*i*) *The Posterior Superior Dental Branches.*—These arise from the trunk as it is about to enter the infra-orbital canal. Two in number, they immediately bifurcate, and pass downwards towards the maxillary tuberosity. They supply the *gums* and neighbouring mucous membranes of the *cheek*. Traversing the posterior dental canals on the zygomatic surface of the maxilla, and passing from behind forwards to the body of the bone, they then communicate with the

(*ii*) *Middle Superior Dental Nerve*, give off branches to the antral mucosa, and pass into the pulps of each of the three *molars*.

The pulps of the premolars are supplied by the terminations of the *middle superior dental branch* which is given off in the back portion of the *infra-orbital canal*, and runs downwards and forwards in a special canal in the outer wall of the antrum. It communicates with the posterior and anterior dental branches, through the so-called *Ganglion*

of Valentin with the former, and the so-called *Ganglion of Bochdalek* with the latter.

(*iii*) *The Anterior Superior Dental Branch*, of large size, comes off from the superior maxillary nerve just before it emerges from the infra-orbital foramen. It runs in a special canal in the anterior wall of the antrum, passes from before backwards and divides into a series of branches to supply the pulps of the *canines* and *incisors*. It communicates with the middle dental branch and gives off a small nasal branch, which inosculates with the naso-palatine nerve from Meckel's ganglion.

LOWER JAW.—In the lower jaw: The inferior dental (mandibular) nerve is the largest of the three branches of the inferior maxillary nerve. It passes with the inferior dental artery beneath the external pterygoid muscle, and then between the internal lateral ramus of the jaw to the dental foramen. Running forwards in the dental canal and lying beneath the teeth, as far as the mental foramen, it there divides into *incisive* and *mental* branches. The *incisors* and *canines* are supplied by the incisive branch, the *premolars* and *molars* by the dental branches. (See the Frontispiece.)

The mental branch freely inosculates with the facial nerve.

Physiological Relationships.—The nervous system of the masticating organs when viewed from a physiological and a clinical aspect is of the utmost importance and should be of great assistance in the diagnosing of difficult recondite problems of pain in dental surgery. A knowledge of the topography of the clinical areas of Dr. Henry Head[4] is, on occasion, of the highest value. This learned investigator has established a definite relationship between certain visceral disturbances in head, thorax, and abdomen, with well-marked areas of superficial tenderness on the skin in the neighbourhood. In an elaborate paper, he successfully shows that "each organ of the head (including teeth) stands in relation with one or more areas on the surface. To these areas, pain is referred, and over them the skin may become tender when the normal condition of that organ is disturbed."

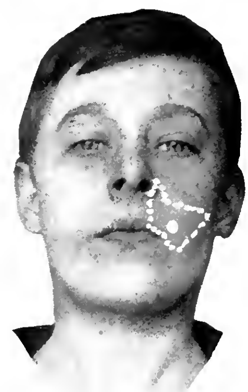
(*i*) The maxillary incisors refer their sensations to the *fronto-nasal* area. This is a racquet-shaped patch extending from two to two and a half inches above the root of the nose, to the junction of the hairy

scalp with the forehead, in a vertical direction, and horizontally, at the level of the eyebrow, to a spot three-quarters or one inch outwards from the median line of the face. It passes down the side of the nose and terminates at the upper part of the *alæ nasi*. The midline is unaffected. The "maximum point" of intensity is over the orbital ridge of the frontal bone, at a spot about half an inch from the median line.

Fig. 249

The fronto-nasal area (maxillary incisors). In this and the succeeding figures, the "maximum spots" are indicated.

Fig. 250



The nasolabial area. (Maxillary canine and first premolar.)

(*ii*) The maxillary canine and first premolar refer to the same area, *viz.*, the *naso-labial area*, that is, over the upper lip, tip, and under surface of the nose and on the cheek, including a portion also of the lower lip, extending outwards to a line dropped from the external canthus of the eye.

(*iii*) The second upper premolar may refer either on to the *temporal* or *maxillary areas*. Of these, the former occupies a position over the temporal fossa, above a line, three or four inches long, uniting the external canthus of the eye with the upper part of the insertion of the ear, its anterior border being three inches from the middle line. The "maximum spot" is in the temporal fossa, immediately above the upper border of the zygoma.

(*iv*) Of the latter, the *maxillary area* is associated with disturbances of the first maxillary molar and hard palate, as well as the premolar referred to. It lies over the maxilla as far forwards as the lateral fold between the nose and the cheek. The upper border corresponds to the lower orbital margin, the lower border to a curved line joining a point on the cheek, close to the fold between the alæ of the nose and the upper lip, with a point immediately posterior to the bony orbit. Its apex is placed about three inches from the median line of the face on a level with the eyebrow.

FIG. 251

The temporal area. (Maxillary second premolar.)

FIG. 252

The maxillary area. (Maxillary second premolar or first molar.)

(*v*) The second and third upper molars refer on to the *mandibular area*. This, roughly triangular in shape, lies over the coronoid process, the ramus, and part of the body of the mandible. It includes the tragus of the ear, the "maximum point" being placed in front of the tragus, and extends as far forwards as a line dropped vertically from the external canthus of the eye.

(*vi*) The *Mental area* is associated with disturbances of both the mandibular incisors, canines, and first premolar. It covers a surface of which the upper border slopes backwards from the angle of the

mouth to a line dropped vertically from the external canthus. The lower lip, not the point of the chin is included. It crosses over the lower border of the body of the mandible as far as the fold which separates the chin from the neck. The "maximum spot" is situated over a line dropped from the angle of the mouth, *i. e.*, close to the orifice of issue of the mandibular nerve through the mental foramen. A portion of the anterior surface of the tongue may be similarly tender.

Fig. 253

The mandibular area. (Maxillary second and third molars.)

Fig. 254

The mental area. (Mandibular incisors, canine and first premolar.)

(*vii*) The second lower premolar refers to the *mental* or the *hyoid* area. The latter is placed partly over the ramus of the mandible, and partly behind its posterior border. It extends up to the mastoid process of the temporal bone, and the lobule, but not the tragus of the ear. Here there may be two maxima: one situated below the angle of the mandible, the other in the external auditory meatus, which gives rise to "earache."

(*viii*) The first and second mandibular molars refer to the *hyoid* area.

(*ix*) The lower third molar may produce a tenderness of the skin over the *superior laryngeal area*. Triangular in shape, its apex lies at a spot which is level with a line dropped vertically from the posterior attachment of the ear. The posterior part of the lower border lies just behind the front border of the sternomastoid muscle, and passes forwards to a level of the lower part of the thyroid cartilage. The upper border embraces the fold between the skin and the neck. The "maximum point" is on the anterior border of the sternomastoid at the level of the *foramen Adami*.

Fig. 255

The hyoid area. (Mandibular second premolar, and first and second molars.)

Fig. 256

The superior laryngeal area. (Mandibular third molar.)

It is important to note that these areas do not correspond with the distributions of the peripheral branches of nerves lying over the face.

THE VASCULAR SYSTEM

The pulps and alveolar sockets of the teeth are supplied by the *internal maxillary artery*. The maxillary incisors and canines are supplied by the *anterior dental* branch, running in the *anterior dental*

canal of the infra-orbital division of the third stage of the *internal maxillary artery.*

The premolars and molars are supplied by the *posterior dental* artery, from the third stage of the same.

The mandibular incisors and canine obtain their vascular supply from the *incisive* branch of the *inferior dental artery* and the premolars and molars from the *inferior dental artery* itself.

It must be remembered that the blood supply of the teeth themselves—as apart from the periodontal membrane—is very peculiar. Not only is there no collateral circulation amongst the arteries, and the veins are non-collapsible and valveless as described elsewhere,[5] but in addition and more important still, as age advances, the blood supply becomes materially diminished on account of the closure of the apical foramina. This closure and often complete obliteration seriously menaces the life history of the pulp. In the opinion of the writer the pulps of people over thirty years of age begin to undergo degenerative changes, through the diminished nutrition on the part of the blood.

Instances often occur where nerve pains in teeth (odontalgia) are ascribed to a faulty metabolism on the part of the nerves themselves. In the pulp an elevation of the blood pressure or a chemical change in the hæmal constituents will produce pain of a very intractable type, and be a source of great anxiety to the practitioner, whether he be in dental or general practice. This vascular factor must never be forgotten in the solution of problems of odontalgia of a complex and obscure character.

THE LYMPHATIC SYSTEM

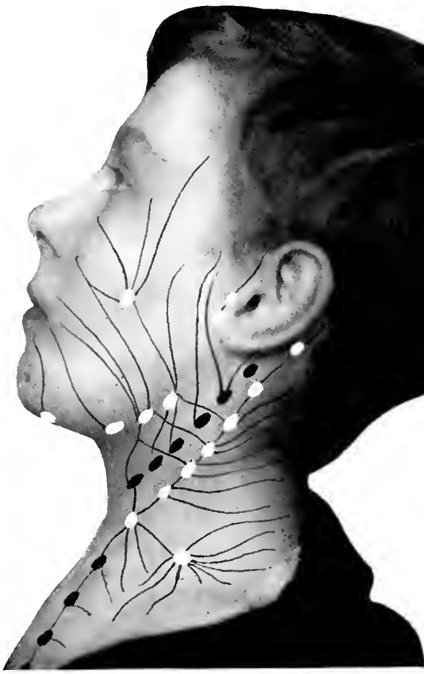
The *submaxillary lymphatic glands* are situated in the submaxillary region, and some of them are imbedded in the gland of that name. The lymphatics of the cheek and face and parotid glands drain into them, also those from the submaxillary and sublingual glands, floor of the mouth, and anterior part of the tongue.

The *deep lymphatics* of the orbits, nasal fossæ, temporal and zygo-

matic fossæ, palate and cheek, drain into the *internal maxillary lymphatic glands* beneath the parotid and the ramus of the mandible.

All of them discharge their streams into the *superficial cervical glands*, which accompany the external jugular vein, and into the *deep cervical glands* which accompany the internal jugular vein.

Fig. 257



The surface markings of the lymphatic system of the face and neck, showing the superficial glands in white, in the cheek, the sub-maxillary, sub-mental, anterior and posterior auricular, and supraclavicular regions, and those lying on the sternocleidomastoid muscle; and in black, the deep lymphatics along the carotid sheath beneath the sternocleidomastoid muscle.

In this way carious teeth in the mouths of weak debilitated children will at times be associated with enlarged, indurated submaxillary glands and cervical glands, in much the same way as with enlarged tonsils and adenoids. It would appear, however, that enlarged tonsils and the presence of adenoids are much more frequently the cause of glandular enlargement than are carious teeth.

Cases of carcinoma of the soft palate are associated with enlarge-

ment of the glands beneath the sternomastoid, as are also sarcomata of the tonsils—one of the few instances where this form of malignant disease is disseminated, not through the vascular system, as usually is the case, but by means of the lymph stream itself.

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4. Head. "Distribution of Sensation with Especial Reference to the Pain of Visceral Diseases," *Brain*, Part III, 1894.

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CHAPTER XII

THE GINGIVAL REGION

Introductory.—Character of the Bone of the Alveolar Sockets of the Teeth of Man; the *Anthropoidea* and the *Felidæ*.—Physiological Absorption of Bone.—The Soft Tissues.—The Gingival Trough and its Contents.—The Distribution of the Glands of the Gum.

If any further evidence than that already adduced were required to demonstrate the unique character of the teeth, it could be readily furnished by the anatomical relationships of the gingival region. Here extremes meet; the hardest and most inorganic tissue of the body on the one hand, in direct association—almost continuity—with one of the softest, and another of the most delicate, on the other. The skeletal elements of the body are invariably covered with periosteum or mucous membrane, or fasciæ of muscles, or the muscles themselves, partially or combined. Even the nasal septum and turbinated bones are overspread with thin mucous membrane. In no other portions of the body, except the nails does this condition obtain. And here these conditions only bear a superficial degree of resemblance. For the nails, though epidermal organs, cannot for a moment be compared either phylogenetically, histologically, or physiologically with the teeth, although in the minds of the untutored savage, nails and teeth are not far separable.

During many years, considerable attention has been paid to the diseases which may attack this region. Second only in importance to dental caries are the morbid affections of the periodontal membranes, the bones of the jaws, and the gums. It is important that something should be known concerning the anatomy of these tissues.

In studying the microscopical aspect of the question, Black,[1] who has done much careful work, deals most largely with the tissues of the lower animals. While much useful knowledge is thus forthcoming, it is better to examine with unbiassed mind, and with some minuteness those of Man, and some of the higher orders of *Mammalia* than the Ungulates.

PLATE III

A Human Skull in Norma Basilaris. $\times \frac{1}{1}$

THE HARD TISSUES

The bone of the jaws in which the teeth of Man are implanted are the alveolar processes of the maxillæ and mandible. These processes differ from those of the majority of other bones in that they afford no muscular attachment—the main function of bones—with the exception of some fibres of the broad buccinator muscle, which arises from that part of the alveolar processes which is associated with the molars. It is repeatedly declared that there is a difference between the osseous frameworks of the two jaws, that of the superior being the more cancellous, that of the lower being the more compact of the two. This is true as far as their external and exposed portions are concerned. Compact bone forms a somewhat thicker shell on the outer and inner surfaces of the mandible than in any portion of the maxillæ. But those parts in closer apposition to the necks and roots of teeth are essentially and fundamentally the same.

Peripherally placed on the main portion of the maxillary and mandibular bones, and each affording attachment to peripheral bodies like the teeth, which possess peripheral structures—the terminal branches of the internal maxillary artery and fifth pair of nerves, and the commencing twigs of the internal maxillary vein—the naked eye and microscopical characteristics are identical. A diploëtic tissue, similar in almost all points to that cancellous tissue which intervenes between the two plates of the cranial bones, such as the parietal, the dense compact structure, in normal circumstances, is absent.

The author[3] has elsewhere demonstrated the chief histological features of these bones, and has pointed out in what ways they differ from osseous material in other places. It may be recalled that in the extremely attenuated bone from the canine fossa of the upper jaw, in a subject of ten and a half years, the tissue is scantily supplied with Haversian systems, portions containing no lamellæ and few lacunæ with canaliculi, the matrix being coarsely granular Many of the lacunæ are abrachiate, like those occurring in the bones of some fishes, such as the trout, the salmon, the cod, and grayling.[2]

In the interdental septa, the lattice-like nature of the tissue is similar

to spongy bone in the carpus, tarsus, and expanded ends of tibia and femur. The lamellæ are disposed in lines parallel with the edges of the large openings in the bone, which are filled with medullary substance; and in the alveolar process, the cancellous spaces run longitudinally in the same direction as the long axes of the teeth. The Haversian systems and lacunæ are pronounced, and the thin peripheric lamellæ are slightly denser than in other parts. The free rim, however, is so thin that there is little, if any, room to accommodate any medullary tissue or Haversian canals. It has thus an impoverished blood supply and its vitality is necessarily very low.

The importance of this anatomical feature cannot be too strongly insisted upon. The condition obtains in Man and can also be seen in vertical sections of jaws of the *Anthropoidea* and *Carnivora*, when the outer alveolar plate has been chiselled away. The extremity of the external alveolar plate is considerably thinner than that of the internal alveolar plate as the photograph (Fig. 258) discloses.

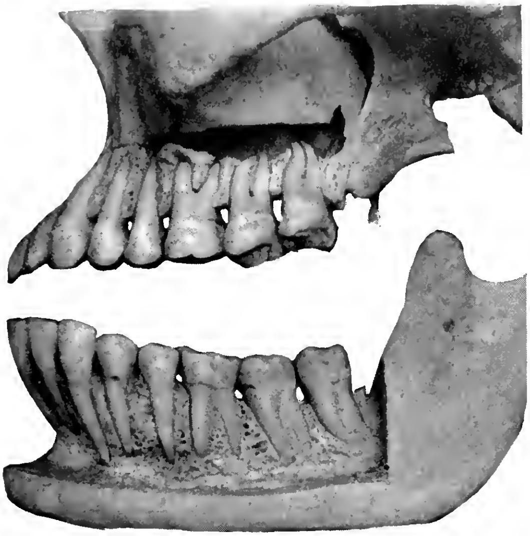
The significance of this fact will be at once appreciated when general disturbances of the vascular system, or general marasmus, or marantic, or senile changes are or begin to become manifest.

The result is absorption of this terminal edge, (*i*) physiological in the case of old age—an elastic term not necessarily governed by the actual number of years of the individual, and (*ii*) pathological, due to diseases of the neighbouring parts. Most animals *in ferâ naturâ* lose their teeth by shedding, through this physiological absorption of their sockets; Man, too, but in the latter, the process is greatly accelerated by incipient disease. The effects of civilization have not only been felt by the teeth, but by their sockets also.

The cancellous nature of the associated bone, and its relative softness can be seen in Figs. 100 and 258. The difficulty encountered at times in the extraction of teeth is often due to a sclerosis and consequent density of the external and internal alveolar plates. In ordinary circumstances the immediate attachment is more or less soft and fragile.

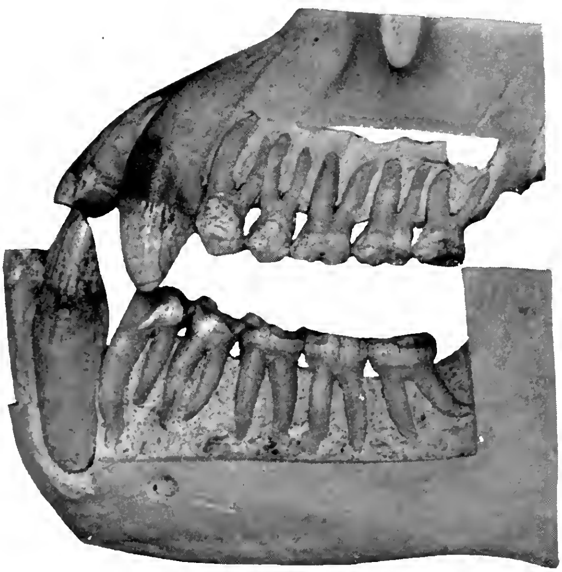
Comparison with the sockets of the anthropoid apes and the *Carnivora* is of great value. In the orang-outang, for instance, the diploëtic tissue is similar to that of Man. The ape, however, is a vegetable feeder, and not omnivorous as is his simian descendant. The teeth

FIG. 258



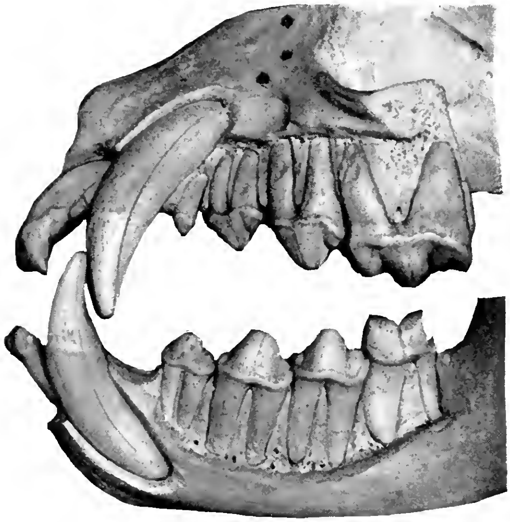
Side view of jaws of an adult man, with the external alveolar plate removed to show the cancellous character of the bone of the sockets. $\times \frac{9}{10}$. *Cf.* also Fig. 194. The premolars are the homologues of the third and fourth premolars in the typical mammalian dentition.

FIG. 259



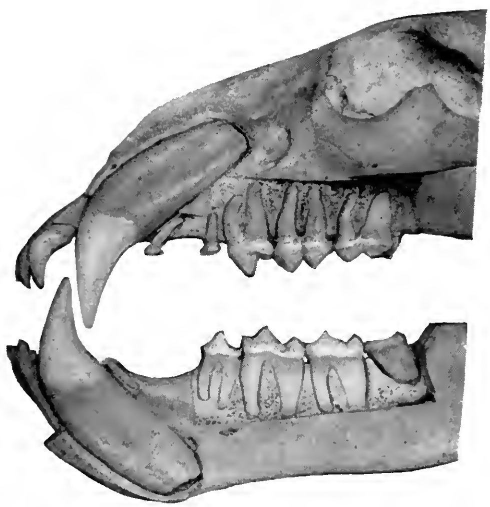
Side view of jaws of an adult orang-outang, with the roots and sockets of the teeth exposed to show the cancellous character of the bone. $\times \frac{1}{2}$.

FIG 260



Side view of jaws of a hyæna (*Hyæna crocuta*). × ½. The external alveolar plate has been removed to show the sizes and positions of the roots of the teeth and the compact nature of the bone of their sockets.

FIG. 261

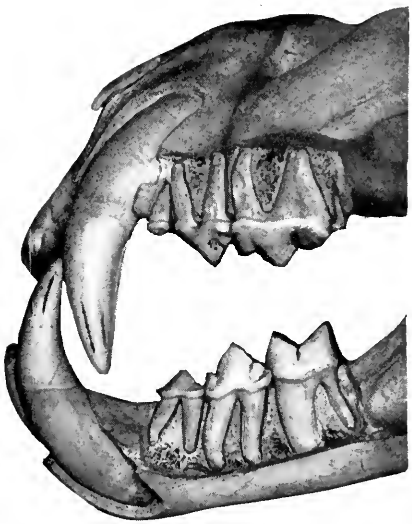


Jaws of a Polar bear (*Ursus maritimus*), the external alveolar plate having been removed to show the cancellous nature of the sockets of the teeth. × ⅔. Two premolars have been shed from the upper and three from the lower jaw.

here, although socketed in cancellous bone, remain, speaking generally, throughout the life of the animal.

In the *Carnivora* the hardest and most enduring sockets are those of the hyæna, whose food is exceedingly tough, and requires most efficient organs for its comminution. The Polar bear—a fish eater—has a less dense alveolar process, as suits its requirements; while those of the tiger, lion, and cat occupy an intermediate position in the scale of density.

FIG. 262



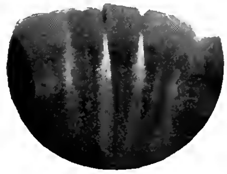
Side view of jaws of a lion, with the roots and sockets of the teeth exposed to show the cancellous character of the bone. $\times \frac{1}{3}$. The fourth premolar is the carnassial tooth.

"Recession of the gums" is a vulgar way of expressing the physiological absorption of bone. "Recession" of the gums *per se* does not, and cannot, take place. It is the natural thing in Man for the alveolar edge to become lost. If the crania exhibited in Anatomical Museums be examined, it will be difficult to select any, except in the young, in which the bone is closely applied to the necks of the teeth, and it will be easy to mistake the macroscopical appearances of jaws which show so-called early stages of "pyorrhœa alveolaris," for those in which, in all probability, there were no evidences of disease at all. A distinction must be made between normal and diseased conditions of the sockets.

FIG. 263

Radiograph of the normal sockets of the incisors of a man, aged about forty years.

FIG. 264

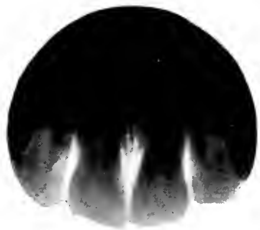


Radiograph of the normal sockets of the mandibular incisors of a woman, aged twenty years.

FIG. 265

Radiograph of the normal sockets of the mandibular molars of a woman, aged twenty years.

FIG. 266



Radiograph of the normal sockets of the maxillary incisors of a man, aged nineteen years.

FIG. 267

Radiograph of the normal sockets of the mandibular incisors of a man, aged nineteen years.

FIG. 268

Radiograph of the normal sockets of the maxillary premolars of a man, aged nineteen years.

FIG. 269

Radiograph of the normal sockets of the mandibular premolars and first molar of a man, aged nineteen years.

FIG. 270

Radiograph of the normal sockets of the mandibular molars of a man, aged nineteen years.

Röntgen-ray photography is of great value in determining the amount and constitution of the alveolar process, though it must be admitted there are differences between radiographs and radiographs. Properly applied photographic films on development, show in otherwise apparently normal mouths this loss of bone in individuals of middle age.

The osseous foundations of the human gingival region are exceedingly variable and weak.

THE SOFT TISSUES, THE GUM AND GINGIVAL TROUGH

The soft tissues include the gum and periodontal membrane. The gum is attached to the cementum at the cervical margins of the teeth; enamel cannot on account of its physical properties afford this attachment. The gum ought to be affixed to the free edge of the cementum, but it varies considerably in the exact site. The gum overlaps the necks in varying degrees. A trough is produced in a narrow relatively deep sulcus, which at the terminal edge is closely approximated to the teeth. The depth of the gingival trough varies in different individuals and in different parts of the mouth. Normally in children from six to twelve years of age, it may measure 2.5 mm. to 4.5 mm. in depth. In children of six or seven years old when the first maxillary incisors have only been erupted a few weeks, it may measure 5 mm. and more, for here the period of complete eruption is not finished.

This sulcus has been called the "gingival space" by Black and others, but it is not in reality a "space," at all events in an academic sense, when the word is employed to denote the "distance between objects," "room," "largeness," etc. A trough—the gingival trough—implies "a long, narrow channel," a "concavity or hollow." The gingival trough is found in reptiles and the lower mammals, and varies in shape and depth. Fig. 272 is a vertical section of the jaws and teeth of the alligator, and Figs. 273, 274, and 275 that of the deciduous teeth of the cat.

In Man the gingival trough contained bacteria in every instance personally investigated by the author, which may or may not be of a

pathogenic character—but more often the former.* It does not contain the salivary corpuscles mentioned by Black; and there is no room, at first, for the lodgement of food. It is, however, a potential "pocket."

FIG. 271

Photomicrograph of the gingival trough which has become a "pocket," from a tooth affected by "*pyorrhœa alveolaris.*" $\times \frac{45}{1}$.

* In the cultures made from the bacterial contents of the gingival trough of the normal mouth of a woman, aged twenty, there were found a *Streptococcus* in long chains, and also a Gram-negative coccus belonging to the *Micrococcus catarrhalis* group of microörganisms. It is unnecessary to state that every precaution was taken to prevent the employment of any alien bacteria in these preliminary experiments.

As far as is yet ascertained, in Man there are no openings into the gingival trough—no ducts of glands. It is bounded internally by the free surface of enamel, and perhaps, at times, by a small amount of

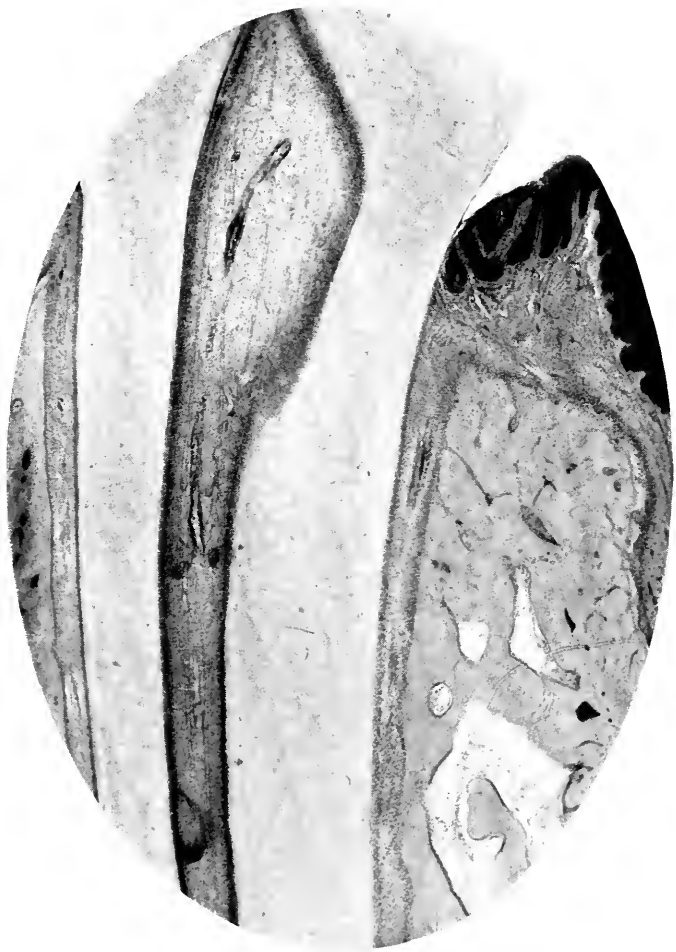
Fig. 272

Photomicrograph showing the gingival trough of a young alligator. $\times \frac{45}{1}$.

the exposed surface of cementum, and externally by the oral epithelium—a narrower layer than usual of the mucous membrane. At its base is the junction of the two, and just beneath is the superficial portion of the periodontal membrane.

The latter is not held closely to the gingival and dental tissues by a so-called ligament—the circular "dental ligament" of Stöhr.[4] In Man it is non-existent, as are also the so-called lymphatics of the

Fig. 273



The gingival region of a cat. $\times \frac{45}{1}$.

periodontal membrane. The gum is freely supplied on its lingual aspect with many mucous alveolar glands, the apertures of the ducts of which open near the gingival trough. The author has not yet found mucous glands on the buccal or labial aspect of the mucous

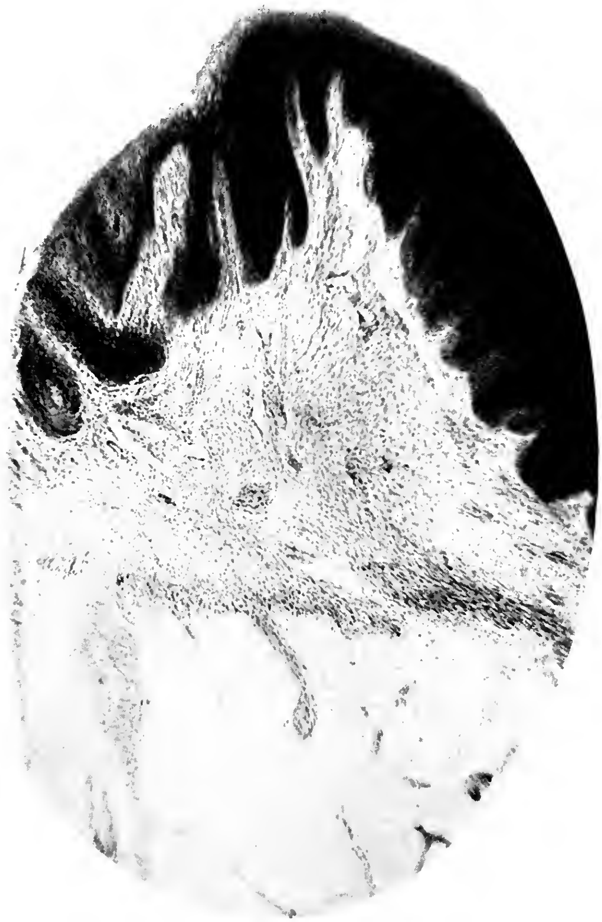
membrane. In a piece of tissue, 8 mm. in length, from the mandible of a man, aged forty-two years, removed from the premolar region, there were no microscopical evidences of glands on the buccal side

Fig. 274

Same as Fig. 273. $\times \frac{110}{1}$.

of the gum. As yet the whole extent of the tissue has not been surveyed, but until this is done it may be inferred that if they do exist in this region they are considerably more scantily scattered than on the lingual side.

FIG. 275



Same as Fig. 273. × $\frac{110}{1}$.

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1. Black. "Periosteum and Peridental Membrane," 1887.
2. Catalogue of the Physiological Series in the Museum of the Royal College of Surgeons of England, 1900.
3. Hopewell-Smith. "The Histology of the Maxillary and Mandibular Bones," *The Dental Cosmos*, 1901.
4. Stöhr. "A Text-book of Histology," 1901.

PLATE IV

A Human Skull in Norma Occipitalis. $\times \frac{1}{1}$

CHAPTER XIII

THE DEVELOPMENT OF THE JAWS AND TEETH

Early Formation of the Head and Face.—Ossification of the Maxillæ.—Of the Premaxillæ.—Changes in the Maxillæ Produced by Age.—Ossification of the Mandible.—Various Theories.—Changes in the Mandible Produced by Age.—The Growth of the Deciduous Teeth.—The Growth of the Permanent Teeth.

THE earlier stages in the development of the jaws and of the teeth differ in the important particular that, while the former are difficult, the latter are easy to follow and describe, the former more uncertain than the latter, probably for the reason that reliable material for examination, on the one hand, is relatively scanty, and, on the other, plentiful. The anatomy of the human embryo has been largely studied by His, Minot, Kölliker, Kollman, Rabl, Ecker, Coste, etc., and thanks to their researches, observations, and published works, a certain amount of knowledge is forthcoming regarding the earliest formations of the jaws.

The primitive mammalian embryo consists of two longitudinal folds of epiblast, rising upon either side of the middle line, or *Medullary groove*, which, growing backwards, meet and form a longitudinal canal. The cephalic extremity of this canal becomes dilated, and soon expands into three enlargements called the *Primary cerebral vesicles*.

The *Primary cerebral vesicles*, which, of course, are hollow, become twice bent forwards on their longitudinal axes, and of these the lower or anterior goes to form the frontal protuberance. They are lined externally and internally with epiblast cells, while between the two a layer of mesoblast spreads itself over the whole surface. The external layer becomes eventually the superficial epithelium of the scalp, the internal layer the nervous system of the encephalon, and the middle mesoblastic layer gives rise to the dermis, the cranial bones, the cerebral meninges, muscles, blood vessels, etc.

The *Notochord*, or *Chorda dorsalis*, is a rod-shaped column of cells,

arising from the hypoblast at the anterior end of the "primitive trace" of the embryo. It extends from the cephalic to the caudal extremities, and its place will be subsequently occupied by the bodies of the vertebræ. Its cephalic termination ends in a mass of tissue which becomes cartilaginous, and gives origin, in the middle line, to the basi-occipital and basi-sphenoid bones, and laterally, each of the occipital bones, the greater wings of the sphenoid, and the cartilage surrounding both primary auditory vesicles. From the front of this mass, two lateral bars are developed, called the *Trabeculæ cranii*, which grow in a forward direction and soon coalesce with each other. From this, a process, the *Fronto-nasal process* arises, and becomes prolonged downwards ultimately to form part of the framework of the face.

Fig. 276

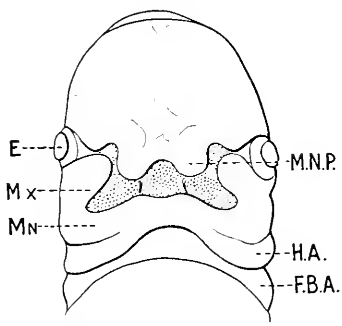
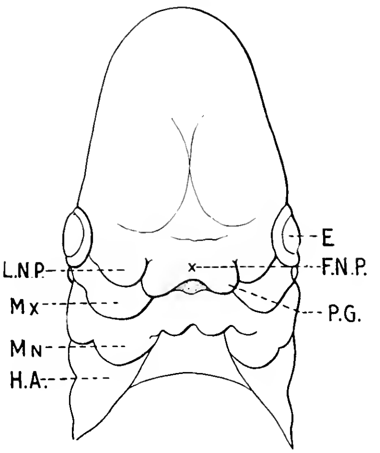


Diagram of the head of an embryo of about four weeks. (After His.) *Mx*, the right maxillary process; *Mn*, the mandibular arch; *M.N.P.*, the globular extremity of the mesial nasal process; *H.A.*, hyoidean arch; *F.B.A.*, the first branchial arch; *E*, the eye.

The face is formed by the development of a series of five arches of soft tissue separated by clefts. The arches may be divided into two groups, one the *Pre-oral*, the other the *Post-oral*, so-called from their position with regard to the buccal cavity. Of these, the former unites with the *Fronto-nasal process*—which, as already noted, is derived from a coalescence of the *Trabeculæ cranii*—and consists of three plates, one central and two lateral. The central is named the *Mid-frontal process*. From it the nasal septum is developed. The lateral plates, separated from the vertical one by deep furrows (the *Primary nasal fossæ*), project downwards in a direction parallel with the *Mid-frontaf*

process, and then, curving towards the middle line, meet with the *Mid-frontal process*, and so isolate the nasal fossæ from the other parts of the face. The lateral plates give origin to the lateral portions of the ethmoid and lachrymal bones, and by joining up with the extremity of the *Mid-frontal process* form the central part of the upper lip and the *Premaxillary bone*.

Fig. 277



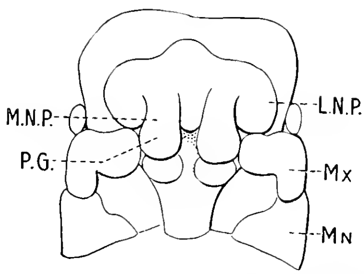
The same as the preceding figure, at a later stage of development. Viewed from below. *Mx.*, the maxilla; *Mn.*, the mandible; *F.N.P.*, the fronto-nasal process; *P.G.*, the *processus globularis; L.N.P.*, the lateral nasal process; *H.A.*, the hyoidean arch; *E.*, the eye.

The *Maxillary processes* arise from the parts situated behind the *Fronto-nasal process*, and are associated with the *Post-oral* or *First visceral arch*. Descending for a short distance, they form the external wall of the orbit, and also its floor, by passing inwards and meeting the lateral plates of the *Fronto-nasal process*. Extending farther, in an inward and downward direction, they join the *Mid-frontal process*, and with it, complete the alveolar arch and the maxillary bones. Extensions of the inner margins of this arch, on either side, produce the *Palatal processes*, which, coalescing in the middle line, form the vault of the palate. In front they do not unite, but leave a permanent lacuna, which eventually becomes the anterior palatine foramen.

Of the post-oral arches, the first is concerned, perhaps about the twentieth day of intra-uterine life, with the production of the *Mandibular arch*, and contains Meckel's cartilage; and between it and the

Pre-oral arch the buccal cavity is formed, which thus consists of mesoblastic tissue, having a layer of epiblast on its inner surface. An involution of epiblast occurs, which elongates until it comes into contact with the upper part of the alimentary canal; the intervening tissue—all the layers of the primitive blastoderm—soon becomes absorbed, and the mouth (*stomodæum*) and alimentary tract become one continuous canal.

FIG. 278



The same at a later stage, showing the roof of the mouth; the mandible has been removed in order to display more clearly the parts. Lettering as before, *M.N.P.*, mid-nasal process.

To recapitulate:

(*i*) The premaxillary bone is developed by the union of the *mid-frontal process* with the lateral plates of the *fronto-nasal* processes:

(*ii*) The *palate* and (*iii*) *maxillary bones*, from the coalescence of the palatal portions of the *maxillary process* of the *first visceral arch*, with the *mid-frontal process*, and

(*iv*) The *mandible* from the first *post-oral* arch.

About the twenty-ninth day of intra-uterine life the embryo measuring 7.5 mm. in the vertex-breech diameter,* the mouth is a wide cavity having in *front*, the *fronto-nasal* process, *behind*, the *mandibular arches*, and *on each side*, the lateral processes, called the *maxillary processes* which project forwards between the optic vesicles and mandibular arches.

At the fourth week, the lateral and mesial nasal processes appear; these were originally the furrows between the olfactory pits.

At the eighth week, the embryo measuring 30 mm., the ossification of the maxillæ begins.

* In fœtuses which measure from 100 to 220 mm. the vertex-breech millimetre length equals approximately their age in days.

OSSIFICATION

The ossification of the jaws begins at an extremely early age, that of the mandible commencing before that of the maxilla. Of all the bones, the mandible is the second to begin to be formed, the first being the clavicle, and the upper jaw the third.

The details of development have been studied and described in Great Britain, among others by Callender,[5] Humphry,[7] Parker,[15] Bland-Sutton,[3] Thane,[22] Low,[10] and Fawcett;[6] in France by Magitot,[11] Masquelin,[12] Testut,[21] Julin,[8] Rambaud and Renault;[16] in Germany and elsewhere by Kerckring,[9] von Bardeleben,[1] Baumüller,[2] Strelzoff,[20] Schaffer,[18] Spix,[19] Meckel,[14] Mies,[13] Toldt,[23] and Wolff.[24]

Maxilla.—It is uncertain from how many centres the bone is ossified. They are deposited in membrane, and the method of deposition of calcific material is similar to that of intra-membranous ossification of bone in other parts. They appear in embryos of 30 mm. About the tenth week, there are two portions of the bone—one the maxilla proper, the other the premaxilla. The intermaxillary suture persists till adult age, but does not pass on to the facial surface, probably because the anterior wall of the sockets of the incisors is formed, not by the premaxilla, but by an outgrowth from the facial portion of the maxilla proper.

The antrum of Highmore is developed at an earlier period than any other of the accessory nasal sinuses. It makes its appearance as a shallow groove on the inner aspect of the cartilaginous nasal capsule, about the fourth month of intra-uterine life, and enlarges continuously until after the completion of the permanent dentition.

Areas of Ossification.—According to Schäfer[17] there are six areas of ossification, as follow:

(*i*) The *Orbito-nasal* centre—situated in that portion of the body of the bone which lies *internal* to the infra-orbital canal, and includes the inner part of the floor of the orbit, and the outer wall of the nasal fossa;

(*ii*) The *Malar* or *zygomatic* centre—which forms that part which lies *external* to the infra-orbital canal, and includes the zygomatic process;

(*iii*) The *Palatine centre*—which gives origin to the palatal process posterior to Stenson's canal with the adjacent part of the nasal wall;

(*iv*) The *Premaxillary* centre—forming the front part of the alveolar process which has the incisors implanted in it, and is the homologue of the premaxillary bone in the lower vertebrates;

(*v*) The *Nasal* centre—which gives origin to the frontal process and bone above the canine; and

(*vi*) The *Infra-vomerine* centre—which lies between the palatine and premaxillary areas, and beneath the vomer. This centre, together with the corresponding centre in the bone of the opposite side, separates the foramina of Stenson from each other.

These centres are supposed to appear, as already noted in embryos of 30 mm. long, about the sixtieth day, and to fuse with one another from the seventieth to the eightieth day.

On the other hand, an alternative theory is held[1] that each maxillary bone arises from *one* centre of ossification as a membranous bone, which is situated at a point in the neighbourhood of the canine tooth germ, external to the cartilaginous nasal capsule.

From this centre three processes radiate, *viz.:*

(*i*) A *Nasal* process growing upwards;

(*ii*) An *Alveolar* process extending downwards and thickened at the base to form the malar process; and

(*iii*) A *Palatine* process, developing inwards. The alveolo-malar process grows backwards and becomes bifurcated to allow the anterior dental nerve to pass.

The *external alveolar border* is developed from cartilage, being ossified by extensions of bone from the main mass: the *internal alveolar plate* appears to come as a downgrowth from the palatine process.

In the absence of further research, it may be perhaps concluded that the six centres of ossification, described by Schäfer, are really not separate centres, but extensions from one central point as just described.

CHANGES IN THE MAXILLA PRODUCED BY AGE.—At *birth*, the vertical diameter is less than the transverse or antero-posterior. The body of the bone consists of little more than the alveolar process. The sockets of the dental germs reach almost up to the floor of the orbit. The antrum appears as a slit-like furrow on the outer wall of the nose.

In *adult life*, in consequence of the development of the alveolar process, and enlargement of the cubical capacity of the antrum, the vertical diameter becomes the greatest of the three.

In *old age*, the vertical diameter becomes diminished, the alveolar process undergoes physiological absorption and the teeth are shed. The lower portion of the bone becomes contracted and diminished in thickness.

FIG. 279

The skull of an adult man whose teeth show marked attrition and pigmentation. × $\frac{1}{2}$.

The Premaxillary Bone.—Reference to Albrecht's investigations have already been made (see Chapter III). On the authority of Professor Fawcett, as well as others, there probably is in Man, only one centre of ossification for each bone.

It is situated, like a bridge, over the interval between the two incisor

germs. A piece of the outer alveolar border, and a part of the nasal process are formed from that portion of it which is near the second incisor.

At a later period the premaxilla consists of two parts: (*i*) A *Processus lateralis*, or facial part, and (*ii*) a *Processus medialis*, which runs backwards on the mesial surface of Stenson's foramen. Still later, two wedge-shaped processes grow backwards from the facial portion

FIG. 280

The skull of an aged person. × $\frac{3}{7}$.

to meet the palatine processes of the maxilla proper, which cause the two sutures seen on the under surface of the whole bone. Finally, a downgrowth of bone occurs to form the anterior alveolar wall, and hides from view the two incisors and the anterior dental nerve.

The Mandible.—A brief *resumé* of the theories held by the most eminent anatomists regarding the ossification of this bone must now be given.

About two and a half centuries ago, Kerckring[9] studied the development of the mandible, and believed that the coronoid process possessed a separate centre of ossification.

Spix,[19] at the beginning of the Nineteenth Century, added a fifth centre—"the piece of Spix"—otherwise the *Splenial* centre—to the other four previously described by Autenrieth, *viz.*, one each for the coronoid process, the condyle, the angle, and the horizontal portion of the body of the jaw.

FIG. 281

The same—side aspect. $\times \frac{3}{7}$.

Meckel[14] discovered the cartilage which bears his name, in 1821; and Callender[5] was the first to show that this cartilaginous rod becomes ossified. To this portion he gave the name of the *Mento-Meckelian centre.*

Renault and Rambaud[16] describe six centres, and give the dates of their appearance and fusion.

Bland-Sutton,[3] in 1883, described six centres—of which five corresponded to those described by Spix, the sixth representing the Mento-Meckelian of Callender.

The following drawing from his paper gives the positions of these centres:

He writes: "So far as I have been able to observe, the nucleus marked *D* in Fig. 282 is the first to appear; from this centre the larger part of the body of the bone is formed. At first it resembles a shallow trough lodging the cartilage.

Fig. 282

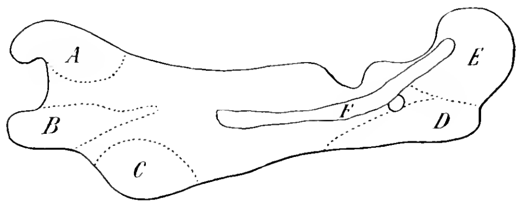


Diagram of the centres of ossification of the mandible at about the tenth week of intra-uterine life. (After Bland-Sutton.) $\times \frac{10}{1}$. *A*, the coronoid; *B*, the condyle; *C*, the angular; *D*, the dentary; *E*, the Mento-Meckelian; *F*, the splenial centre.

"The nuclei for condyle, coronoid, and angle follow so rapidly that it is difficult to determine their order. About the same time, osseous granules may be seen in the perichondrium surrounding the distal end of Meckel's cartilage, gradually invading its substance.

"As soon as the various centres make their appearance, a thin network of osseous tissue quickly connects them. When this occurs, a thin shelf of bone will be found immediately above Meckel's cartilage and the inferior dental nerve. This latter osseous streak lies on the inner side of the developing bone, quite distinct from the other centres, and represents the splenial. Now is the very best time to observe the various nuclei, particularly if the bone is rendered transparent by means of alcohol and oil of cloves. Its appearance is very striking. The bone presents the familiar shape of the fœtal jaw, but its texture reminds one of a spider's web, the various centres showing like flies entangled in the mesh.

"The order of events may be arranged in stages for the sake of clearness thus:

"1. Meckel's cartilage appears.

"2. Dentary is seen below.

"3. Centres for condyle, coronoid, angle, and Mento-Meckelian.

"4. Network of osseous tissue connects them together.

"5. Splenial appears as ledge of bone supporting teeth.

"6. Disappearance of Meckel's cartilage from jaw, and fusion of splenial.

"The splenial element is interesting on account of its relation to the developing teeth. On its first appearance it stands out at right angles to the dentary, serving to separate the teeth germs from Meckel's cartilage. If at the fourth month of intra-uterine life the tissues on the inner side of the jaws be carefully dissected away the splenial will be observed forming a distinct ledge of bone, supporting on its superior surface the dental follicles like flasks on a shelf; immediately beneath it runs Meckel's cartilage and the nerve. As the cartilage atrophies, the splenial extends downwards to fuse with the dentary immediately below the nerve; in this way the mylohyoid branch gets shut off from the main portion of the inferior dental nerve. After the fourth month it extends vertically to form the inner wall of the maxilla, all trace of its originally separate condition being thus completely lost, the bone then assuming the condition, which it presents at birth, with which we are all so familiar.

"Let me now offer evidence of a different character of the compound nature of this bone. In the year 1814, the celebrated French anatomist, Serres, in a paper read before the Académie des Sciences, Paris, propounded certain laws bearing on ossification. Among them was one termed the 'Loi de Conjugaison,' by which he showed the various foramina in bones to result from the opposition of two or more distinct bones or distinct centres of ossification. To this law there were many exceptions; among the more unstable were certain foramina in the temporal bone and the inferior dental foramina.

"When I first took up the subject of nerve foramina, Serres' researches were quite unknown to me, and I took as my guide this rule: 'Whenever a nerve passes through a bone it marks the confluence of two or more ossific centres.' Among the earliest bones to yield under this method of analysis were the temporal and the inferior maxilla;

later I became acquainted with Serres' paper, the greater part of which is published as a footnote in the French translation of Meckel's 'Anatomie Comparée,' vol. iv. Much to my satisfaction I found that my method had yielded far more satisfactory results and had banished two of the apparently most obvious exceptions to the law, and it is most interesting to trace out the intricate pathways by which many nerves quit the cranial cavity in order to avoid piercing an ossific centre.

"Applied to the lower jaw, the rule stands thus: The nerves concerned are the inferior dental, mental, and mylohyoid. The inferior dental enters by the foramen of the same name, formed by the coalescence of the coronoid, condyloid, dentary, angular, and splenial elements; the nerve then travels in a tunnel formed on the outer side of the dentary and on the inner side of the splenial. The mental branch passes out through a fenestrum formed by dentary and Mento-Meckelian ossification.

"The mylohyoid runs in the groove which once lodged Meckel's cartilage, the sulcus also, corresponding to the junction of splenial with dentary. As the inferior dental passes along the canal, it sends up twigs to the teeth, and these twigs occupy foramina or spaces between the splenial and dentary. The relation of nerves thus lends additional help in unravelling the mystery."

Bland-Sutton, from this point, proceeds to the comparative side of the question, quoting the condition in the dog-fish, the sturgeon, the *amia*, the cod, amphibia, and reptiles. He finally gives a table of homologies thus:

Man.		Fish.
The Mento-Meckelian	is the homologue of the	Mento-Meckelian.
The Angle	corresponds with the	Angular.
The Condyle	corresponds with the	Articular.
The Coronoid	corresponds with the	Surangular.
The Splenial	corresponds with the	Splenial.
The Dentary	corresponds with the	Dentary.

The latest investigations in this subject are those of Professor Fawcett and Mr. Low. Curiously coincidental—although the research was carried on entirely independently—they were published more or

less simultaneously, and they are so much alike that they are accepted by such an authority as the editor of Gray's *Anatomy*.

Fawcett's Summary.—"*First.*—The jaw in its ossification is not so complex as some would have us think, but it is, for all that, complex, involving (*a*) Meckel's cartilage at its anterior extremity; (*b*) the membrane on the outer side of Meckel's cartilage; and (*c*) at least one accessory cartilage which is found in the condyle, neck, and base of the coronoid process of the jaw. These statements apply to each half of the jaw.

"*Second.*—In order of sequence, ossification occurs first in the membrane between the mental nerve and the middle line, and extends backwards under the mental nerve. Next, ossification commences in Meckel's cartilage, about the tenth week of fœtal life, in the region of the mental foramen, and gradually extends inwards. That part of the jaw then between the mental foramen and the symphysis is compound in origin, being partly cartilaginous, partly membranous, not entirely cartilaginous, as Bland-Sutton says. Finally, ossification takes place in the accessory mass of cartilage in the condyle and the root of the coronoid process at the third month.

"*Third.*—There are no separate centres in membrane for either the coronoid process, or for the angle, or the so-called splenial, all these parts being outgrowths, as it were, from the main mass.

"*Fourth.*—The inner alveolar border is developed in two parts by ingrowths from the main mass, and at two different periods, *viz.*, that part behind the mental foramen appearing first, and elongating from before backwards, that part in front of the foramen appearing later and growing from behind forwards.

"*Fifth.*—The canal for the nerves is completed by the growth of spicules of bone from one alveolar border to the other, over the top of the nerves, the mental nerve being first so covered, then the incisive, and much later, the inferior dental, near the permanent inferior dental foramen.

"*Sixth.*—The sockets of the teeth become bony comparatively late, that of the canine appearing first.

"*Seventh.*—Meckel's cartilage becomes incorporated in the jaw anteriorly by the development of upper and lower shelves, which

gradually close over it; behind the mental foramen these shelves do not meet, and Meckel's cartilage is consequently not included in the jaw, but gradually atrophies.

"*Eighth.*—I do not think that Meckel's cartilage atrophies to form the internal lateral ligament of the jaw. This ligament in the fourth month can be seen quite distinctly in an ordinary dissection to be independent of Meckel's cartilage."

LOW'S CONCLUSIONS.—The above description corresponds fairly closely with Low's observations, with the exception that the latter author describes a further cartilaginous patch situated on the anterior border of the coronoid process. In both instances serial sections, and not clarified specimens, were examined.

FIG. 283

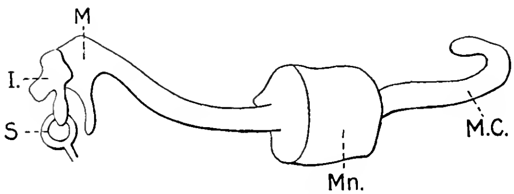


Diagram of Meckel's cartilage, showing its association with the malleus at its posterior extremity: *M.C.*, Meckel's cartilage; *Mn.*, mandible; *M.*, malleus; *I.*, incus; *S.*, stapes.

The following are the conclusions arrived at by Low:

Each half of the mandible is developed from the *dentary* centre in membrane; the *splenial* centre does not exist separately, but is really an extension of the dentary which goes to take part in the formation of the internal alveolar plate.

Meckel's cartilage has no share in the formation of the bone except towards its anterior portion, *viz.*, that situated just below and inside the positions occupied, in future, by the sockets of the first and second incisors. Here it becomes ossified and incorporated with the mandible. The extreme front terminations of the cartilage persist throughout intra-uterine life as one or more cartilaginous nuclei or nodules behind the symphysis; these extremities never fuse.

At a somewhat later stage certain accessory cartilaginous nodules appear in connection with the primary membranous bone. A *condylar*

cartilage and a smaller *coronoid cartilage* are well defined, as also are smaller cartilaginous nuclei situated "along the margins of both alveolar walls in front as well as along the front of the lower border of the jaw." They, however, are not separate centres of ossification, but become ossified by extension from the growing bone around. Apparently, according to this author, no definite cartilaginous nucleus for the angle exists; and there is only one centre of ossification, *viz.*, the *dentary* for each half of the bone.

CHANGES IN THE MANDIBLE PRODUCED BY AGE.—*At birth* the bone consists of two lateral halves, joined at the symphysis by fibrous membrane. The framework of the body is very thin and contains the sockets of the two deciduous incisors, the canine and the two molars in each half. The sockets are only deep enough to enclose the partially developed teeth, and are separated by imperfect septa of bone, those of the first mentioned being wider at the base than above.

The calcification of these deciduous teeth has usually advanced so far as to form, roughly, half the crown of the first incisor, one-fourth of that of the second incisor, one-sixth of that of the canine, the whole of the morsal surface of the first molar, and the united cusps of the second molar. The enamel is more or less half its ultimate thickness.

The mandibular canal, large in size, runs near the inferior border of the bone; the mental foramen opens beneath the socket of the *first* molar; the neck of the condyle is short and about on the same horizontal plane as the upper portion of the alveolar process. The coronoid process is large, and situated at right angles to the body of the bone. The angle is obtuse and measures about 175 degrees.

After Birth.—Union of the lateral halves occurs during the first year *post natum*. The body undergoes a lengthening and a deepening. The former takes place, chiefly, in that part behind the mental foramen, for the accommodation of the three additional permanent molars; the latter in two directions: (*i*) In the alveolar part, to allow for room for the growth of the roots of the deciduous teeth, and the crypts of their permanent successors; and (*ii*) by additions to the anterior or sub-dental portions for the attachment of the muscles of mastication. The greater part of the body now lies above the external oblique line.

After the second dentition is completed, the orifice of the mental foramen is situated between the first and second premolars; the mandibular canal itself lying just above the level of the mylohyoid ridge. The angle at the fourth year is 140 degrees, and the alveolar arch describes a segment of a circle.

In adult life, both alveolar and basal portions of the jaw are of equal depth; the mandibular canal runs parallel with the mylohyoid ridge; and the mental foramen opens midway between the superior and inferior border. The angle approximates now 90 degrees, the ramus being nearly vertical. The alveolar arch has become a parabola.

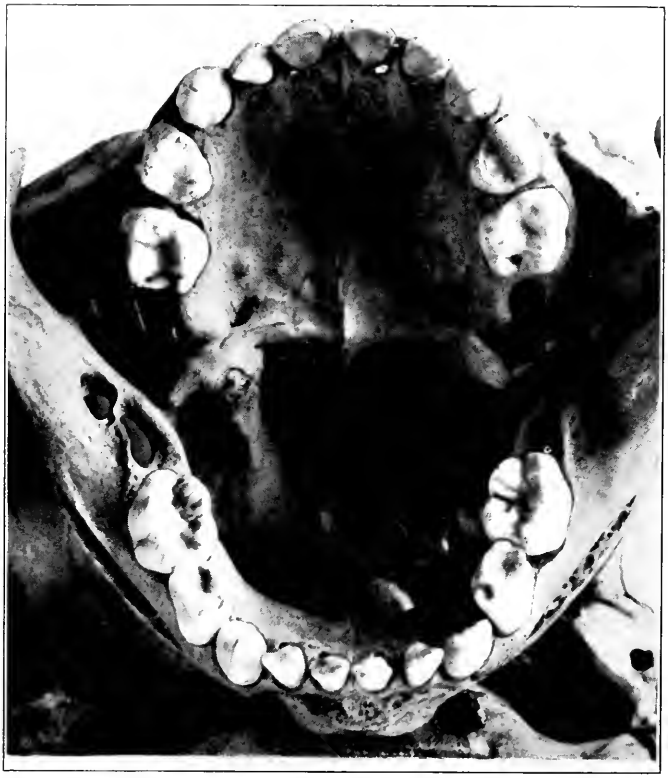
In old age there is a great reduction in size, through the shedding of the teeth as a physiological or pathological process. The result is loss by absorption of the alveolar process. The greater part of the bone now lies below the oblique line. The mandibular canal lies close to the alveolar body; and this fact probably accounts for the obscurity of pains which sometimes occur in edentulous persons who are wearing dentures. The neck of the condyle assumes somewhat the infantile position, being bent backwards; the angle is again slanting (nearly 170 degrees), and the ramus is no longer vertical, but obliquely placed with regard to the body of the bone.

THE GROWTH OF THE DECIDUOUS TEETH

The various stages of development of the teeth at birth have already been detailed. It now remains to note the subsequent changes.

The anterior surfaces of the maxillary first incisors are exposed through absorption of their crypt walls at about eight and a half months *post natum*, but their thin incisive edges remain at a level with the alveolar margin, while they themselves occupy a slightly prominent position in the dental arch. The second incisors are placed in a circle which passes behind these teeth, and also the canines which are still enclosed in bone. The same remark applies equally to the mandibular series, with the exception that the second incisors are more in alignment with the first. The crowns of the latter are completed and their cervical constriction beginning to be manifest.

FIG. 284



The deciduous teeth of a child. × $\frac{6}{5}$.

FIG. 285

Skull of a child at birth. × $\frac{1}{1}$.

FIG. 286

The same at a later period. × $\frac{1}{1}$.

FIG. 287

The same at a later period. × $\frac{6}{7}$.

FIG. 288

The same at a later period. × $\frac{6}{7}$.

The molar sockets are separated from the floor of the orbit by the rapidly growing antrum.

FIG. 289

The same at a later period. $\times \frac{6}{7}$.

FIG. 290

The same at a later period. $\times \frac{6}{7}$.

About the thirteenth month the maxillary second incisors are in place, and the crowns of the first molars beginning to emerge from the sockets; about five weeks later, the partially complete molars are in occlusion.

About the fortieth month, the incisors are completely formed, the canine roots are as yet only partially developed, the first molars

FIG. 291

The same at a later period. × $\frac{7}{10}$.

are one-fifth, and the second molars are half of their normal length, and it is not until the fifth year that the roots of all the deciduous teeth are fully formed. From examinations of the skulls in the Royal College of Surgeons Museum, it would appear that by the third year the deciduous dentition is complete and fully erupted.

THE GROWTH OF THE PERMANENT TEETH

There are ten anterior successional, and six posterior non-successional teeth in Man.

The Successional Series.—Close before, or soon after, the one hundred and seventeenth day of intra-uterine life, the enamel organs of the permanent incisors and canines are formed, and the premolars slightly later. They occupy sites on the lingual side of each deciduous tooth germ. Ten in number in both maxillæ and mandible, it is established that the anterior ones precede the posterior in their formation.

FIG. 292

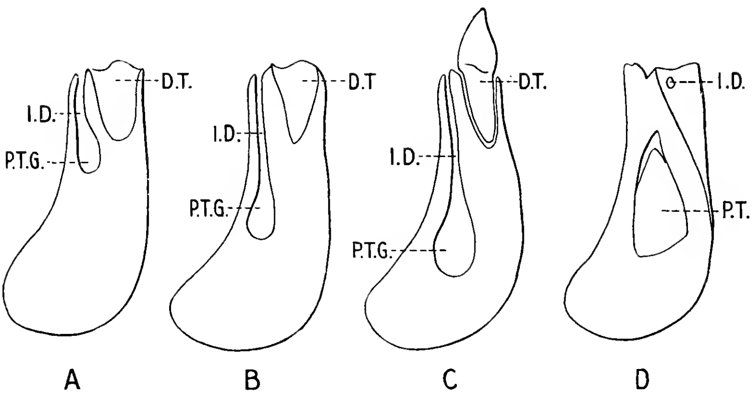


Diagram showing the changes in the shapes of the cavities of the mandible which are consequent on the growth, the teeth of the permanent dentition. (After Blake.) *A*, *B*, *C*, before the shedding of the deciduous teeth; *D* (a lateral view). *D.T.*, deciduous tooth; *P.T.G.*, permanent tooth germ; *I.D.*, *iter dentis*.

These permanent tooth germs rapidly extend downwards or upwards as the case may be, into the soft tissues, acquire dental papillæ and become enclosed in sacs which adhere to the lingual surfaces of the corresponding deciduous tooth germs. The bone of the jaw surrounds both the milk and permanent germs and provides a special cavity on the lingual side for the reception of each of the latter.

Each permanent tooth sac soon grows some distance below and behind the deciduous tooth germ; is at first pyriform in outline and afterwards becomes connected with the germ by a solid peduncle of con-

nective-tissue fibres (the *Gubernaculum*), which lies in a long bony canal (the *Iter dentis*), whose aperture is placed behind the corresponding deciduous tooth (Fig. 292). The bony partition which thus intervenes between the lower part of the deciduous tooth and the crown of the permanent tooth becomes absorbed—probably by a special absorbent organ—as the crown of the latter rises through the gum.

The sockets of the permanent teeth are formed at the same time as the roots become developed.

The Non-successional Teeth.—The six permanent molars in each jaw arise from the backward extension of the common dental lamina, the anterior part of which has already produced the ten deciduous teeth, and the ten successional tooth germs. That part of the *Zahnleiste* which runs behind the second deciduous molar remains unobliterated for a long time, till about the one hundred and twentieth day a special enamel organ begins to appear for the first permanent molar. During the fourth month after birth that of the second molar is similarly developed, and probably about the third or fourth year that of the third molar.

Failure of atrophy of the portions of the tooth band which intervenes between the tooth germs, and persistence of the unabsorbed portions may, in certain circumstances, produce either (*i*) supernumerary teeth, (*ii*) enamel nodules, (*iii*) true gemination, or, at times, (*iv*) epithelial odontomes.

About the fortieth month the permanent incisors, canines, and first molars are completed as far as their crowns are concerned; the earliest traces of calcification are beginning to appear in the first premolars and less than two years later that of the second premolar.

At the time when physiological absorption of the roots of the deciduous incisors is proceeding, the roots of the permanent incisors have begun to develop, the crowns of the canine and premolars are still incomplete, the roots of the first permanent molars are undergoing completion, while the crowns of the second molars are only partially calcified.

The permanent canines at nine years are complete as far as half the root is concerned, and at twelve the calcification is practically finished; of the first premolars, one-fourth of the root at the ninth year and the

whole at the twelfth; of the second premolar, at nine years the commencement of the calcification of the root and at twelve years its completion; of the first molar, the growth of the roots ceases about the tenth year; of the second molar, commencement of calcification of the roots is observed and not completed till about the fifteenth to the seventeenth year; of the third maxillary molar, at about twelve years the crown is more or less calcified—the mandibular molar is less advanced, and growth ceases from the seventeenth to the twenty-second year.

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CHAPTER XIV

THE DYNAMICS OF ERUPTION

Introductory.—Certain Facts.—The Radicular Elongation Theory.—Interstitial Growth of Bone.—Deposition of Bone.—Blood Pressure.—The Epithelial Theory.—The Gubernaculum.—The Influence of Nutrition.—The Dates of Eruption.

Introductory.—The process of the eruption of the teeth is a physiological mystery, as is that of growth generally. Many theories have been formulated to attempt a solution, but none are entirely satisfactory. The application of a substantial hypothesis must extend to both deciduous and permanent dentitions; to teeth which appear at a later or earlier period than when they are expected—the process of apparition, retarded by some obscure or obvious circumstances, as in cretins, or expedited by general disturbances of growth, as by syphilis; to teeth which erupt in anomalous positions; and to teeth which, though fully developed, do not erupt at all. In considering this rudimentary question, it will be advisable to study certain ascertained facts, to narrate various theories, and to draw conclusions.

Too much attention has been given to, and importance placed upon, the examination of the naked-eye appearances of developing teeth. The dynamics of eruption are concerned, not only with the nature of the body which moves, but with the cause of the motion which impels it to the surface, and they begin to work long before any appreciable alteration could become visible to the unaided eye. Histology will help, however, in the elucidation of the matter, and also the histogenesis of the teeth and jaws of the higher mammals, such as the *Carnivora* and the *Primates*. The deductions made from a consideration of the emergence of the teeth from the gum in the mouths of fishes are wholly indefensible, especially when one of the lowest types of fish—the *Chondropterygii*—is employed.

Certain Facts.—The deciduous tooth germs are, from the commencement of their formation, so placed that they almost invariably

PLATE V

The Mandible of an Adult. $\times \frac{1}{1}$

bear a direct relationship to the developing bone of the jaw. In coronal sections through the head of a human embryo of 12 cm. length, four areas of ossification appear. These occupy the site of the future alveolar processes. These osseous areas, as observed in such a section, are bifurcated outwardly, *i. e.*, on the oral side, and towards the middle of the branching the tooth germs are directed. In both maxilla and mandible they are turned towards the middle line. The amount of bone formed, say at the fiftieth day of intra-uterine life, is already considerable; that of the tooth germ only small; the two are quite disproportionate. The rate of development between them is also unequal.

By about the hundred and twentieth day a definite bony cup has been produced, which gives lodgement to the still rapidly growing, but very incomplete tooth germ; and shortly afterwards, perhaps twenty or thirty days, this cup is a deep wide-mouthed gutter of bone. The free margins of the cups subsequently become narrower, and at the ninth month (birth) each tooth germ is imbedded in a closed bony sac. Absorption of the crypts placed in the anterior portions of the maxillæ and mandible, begins to take place in Man about the seventh month before birth. It proceeds on ordinary physiological lines at the expense of the superior and anterior surfaces. This absorption is followed, when the crown has emerged through the orifice of bone and gum, by a rapid development of bone above the neck of the tooth. This bony growth keeps pace, *pari passu*, with the elongation of the roots, and the increasing depth of the jaw with the eruption of the teeth.

Eruption is probably a continuous process, though some believe it to be interrupted by periods of repose.[16] It has not been explained why, when once the forces have begun to act, they should suddenly suspend their operations for a varying period of time.

Prior to their being shed, the deciduous teeth become slightly separated from each other. This is accounted for by the growth of the bones which has taken place since they were erupted. They now occupy a more prominent position, due to the increase in the dimensions of the crypts behind, which are beginning to accommodate the larger tooth germs of the permanent dentition.

The sockets, as Mr. Tomes[14] insists, grow up with and are "moulded around the teeth as the latter elongate." "The socket is subservient to the position of the tooth, and wherever the tooth may chance to get to, there the socket will be built around it."

Eruption appears to be subject to the three general laws as defined by Debierre and Pravaz.[5]

1. Teeth of the same denomination appear in pairs;

2. From the point of view of time, those of the lower precede those of the upper jaw;

3. The first deciduous incisors precede the second, the latter the first molars, after which come the second molars or perhaps the canines.

It is a well-known clinical fact that rickets retards and syphilis accelerates dental eruption; but as for the reasons, there are no evidences yet forthcoming. It is noteworthy that both these diseases produce lesions which very largely affect the skeletal tissues, particularly the former, and the retardation or acceleration in eruption may be dependent upon the influence they have in the rate of growth of the bony sockets of the teeth.

At all events, it would seem evident that a direct relationship exists between the growth of bone and the eruption and growth of the teeth —a relationship which has a physiological as well as a pathological side. The hypothetical aspect is quickly becoming the actual one.*

* A case which may, perhaps, throw some light on this obscure subject has recently been described by Mr. A. T. Pitts, in which there was a remarkable partial failure in the eruption of the molars, associated with an arrest of the growth of the mandible. It occurred in a man, aged twenty-three years, who was well developed except with regard to the lower jaw. The only teeth in occlusion were all the incisors and canines, and on the right side, the first upper and both lower premolars. On the left side the mandibular second premolar and the first and second molars were present, their crowns being only just exposed, and directed considerably inwards. Above, a bridge extended from the first premolar to the first molar, which thus rendered it impossible to determine the amount of eruption of these teeth. The second molar was normally erupted. In occlusion, a space of 10 mm. intervened at the widest part. The first right mandibular molar was incompletely erupted. In the right maxilla the premolar and first molar were normal, while the second molar was only just erupting. The patient stated that the condition had remained stationary for some years. Radiographs revealed the fact that there was no diminution in the number of the teeth, the complementary teeth with fully formed roots being still unerupted, including a small, irregular calcified mass behind the second upper premolar. The anterior portion of the mandible in the incisor region was fully developed, but the posterior parts not so. Here the compact bone was greatly reduced in depth: the mandibular canal appeared to be in direct contact with the lower border of the jaw, and no bone intervened between the apices of the roots of the lower molars and the compact bone. The most superficial portions of the alveolar processes seemed to be somewhat denser than usual. (See Fig. 296.)

The governance of the growth of the body—including the osseous system—would seem to lie in a hitherto insignificant and unsuspected

FIG. 293

Plaster cast of the teeth of a patient affected by acromegaly (see succeeding Figs.), showing method of their occlusion.

FIG. 294

FIG. 295

FIG. 294.—Head of an adult, aged twenty-two years, affected with acromegaly. The face has become greatly elongated and enlarged, due chiefly to the increase in size of the maxillæ and mandible, especially the latter. The nostrils are large and broad, the eyelids thickened, the ears enormously hypertrophied. Bitemporal hemianopia is present.

FIG. 295.—The same as preceding Fig.—side view.

quarter, and evidence seems to be accumulating to show that the pituitary body, which weighs only from 5 to 10 grains,[9] situated near

the anterior part of the midline of the base of the brain, in some, as yet abstruse fashion, presides over the function of growth.

Fig. 296

Radiograph showing incomplete eruption of the mandibular molars. *Cf.* Fig. 240.

Keith[9] has described certain changes occurring in the jaws of Man when associated with acromegaly. He says: "During the eruption of the teeth the growth of the upper and lower maxilla is so coördinated that the upper and lower teeth fall into correct apposition. There are, at least, two factors concerned in this coördination: (1) A

substance evidently derived from the pituitary body which acts on the osteoblasts so that they respond readily to certain stimuli, and (2) certain forces or stimuli which act directly on the jaws. These stimuli arise (α) from the developing teeth; (β) from pressure applied to the alveoli during mastication; (γ) from the direct reaction of the muscles of mastication. The last-named force acts chiefly on the lower jaw." (Figs. 293 and 294.)

It would, therefore, appear that the eruption of the teeth is probably brought about indirectly by a complex physiological process which arises in and is governed by the function (*i. e.*, the secretions) of the pituitary body, and directly by the actual growth of the bone of the jaws which is destined to become the more or less permanent sockets of the teeth—a physiological process as yet but little understood, whose *modus operandi* cannot be reduced to a mathematical certainty, and whose operations terminate with a completion of the growth of the alveolar processes.

It seldom happens that there are irregularities in the order, or in the position of the deciduous teeth—eruption is normal from that point of view.

THEORIES

A brief examination of the theories which have from time to time been advanced must now be made, with the arguments *pro and con*, the most fantastic of the numerous speculations being purposely omitted.

The Radicular Elongation Theory.—This is the simplest as defined by Kölliker,[10] Lévêque,[11] Robin and Magitot,[13] and Tomes.[15] The last-named authority readily admits that against this are the constantly recurring facts that (1) teeth possessing very stunted roots often erupt; (2) that the structural completion of the whole length of the roots does not necessarily prevent a tooth from remaining imbedded in the bone throughout the life of an individual; and (3) that "when a healthy normal tooth is being erupted, the distance travelled by its crown often greatly exceeds the amount of addition to its length, which has gone on during the same period." This last fact is well observed in connexion with the maxillary canines, as also, at times, with teeth which erupt in inverted positions.

Theory of "Bone Currents."—An interstitial growth of bone or so-called "bone currents" was proposed by Coleman,[3] as occasioning the movements of the developing teeth. These "bone currents" were supposed to be peculiar to the jaws, and were accompanied by denudation of the alveolar margins, bringing at length the teeth into proper position.

Deposition of Bone Theory.—Allied to this, was the belief that a deposition of bone at the base of the dental crypts, and also that a certain amount of contraction of the alveolar plates achieved the same object.

Regarding the two latter theories it may be asked: "Why do these forces cease?" or conversely: "Why do not these forces proceed until the occupants are completely forced out of their alveolar sockets?" There is no contraction of the alveolar process about the roots of teeth of persistent growth such as the incisors of rodents.

Blood Pressure Theory.—That the blood pressure in a vascular tissue which lies between the developing tooth and its surroundings is a mechanical factor is a theory advocated by Mr. Constant.[4] He writes: "Assuming that the physiological process of dentinification *can* exercise independent mechanical force, and *is* a factor in the causation of eruption, it must, since action and reaction are equal and opposite, divide the honours with the blood pressure as a factor hitherto quite unrecognized." "The fact that teeth with fully formed roots remain unerupted can be more easily explained by this theory than by any other, because it alone can account for the space obtained for the fully developed roots, which often occupy abnormal positions. In other words, the blood pressure, acting as it does equally in all directions, makes room for the developing root in the direction of least resistance. Normally this is in the direction of the advancing crown, but occasionally it is elsewhere."

It will be observed that in Mr. Constant's description of his conception of this force, he asserts that the blood pressure "acts equally in all directions." If this is so, it would act on the superior surface of the crown of the developing teeth, equally as on the lateral and the inferior surfaces. These suggestions seem to be based upon the nature of the "jelly-like" consistence of the tissue in which the teeth are

imbedded. There is no gelatinous tissue found in this region, as any properly prepared section will demonstrate. Neither is it "extremely vascular." The suggestion almost, if not entirely, implies a condition of hyperæmia around the root follicles. The relationships of the parts which appear in the diagram accompanying his paper are non-existent, the immediate peridental environment being quite inaccurate and exaggerated.

Again it is obvious that microscopical and not macroscopical examinations are required. Further, if this theory was acceptable the blood pressure—unless it was itself stopped—would slowly but surely cause entire extrusion of the teeth.

"Epithelial" Theory.—The "epithelial" theory, ably advocated by Mr. Warwick James,[8] has arisen in connexion with certain persistent epithelial remains of the tooth band and enamel organ, found in relatively small quantities in the jaws over the crowns of erupting deciduous teeth. Their remains, according to this observer, form three principal groups—superficial, intermediary, and deep—near the external surface of the enamel organ, and are "the determining factor in directing the tooth to its fixed position in the jaw." He finds that the epithelium is produced continuously up to the period of eruption, and that there is probably a continuity of epithelial tissue extending between the surface epithelium and the remains of the enamel organ. "A zone of rarefaction exists over the teeth in the stages of eruption." "The path of eruption is prepared by the degeneration of the epithelium; the tissues which are apparently very dense, become loosened and rarefied by the ramifications of the epithelium, and particularly by the changes in the zone of rarefaction." The so-called "glands" of Serres degenerate and diminish the depth of tissue over the crowns of the erupting teeth.

While accounting for the conditions which probably expedite the passage of the teeth from their crypts, through the gum, nothing here is said as to the force of initiation, or how the teeth begin to move. Moreover, the deciduous series apparently only are considered. The histological differences existing in the region around the developing permanent teeth must be reckoned with, and in this respect the

"epithelial theory" fails, nor can it be applied to the eruption of ovarian teeth.

It may, however, be asserted that in these views an advance has been made, particularly in the knowledge as to the dates of the eruption of the deciduous teeth.

Gubernaculum Theory.—A revival of the gubernaculum theory has recently occurred. Mr. Thornton Carter[2] writes: "I am of the opinion expressed by the 'older anatomists' that the gubernaculum is concerned in some way in directing or effecting the eruption of the teeth." "I believe the most important factor, and the only one which provides a satisfactory working hypothesis for the practitioner in dealing with cases of irregularity of the teeth, to be the force exercised on the tooth through the gubernaculum." In a later article he recedes from this position, however, and becomes more guarded, for after dealing with the question from the point of view of the cartilaginous fishes, in which "the mechanism of eruption is constantly in operation unobscured," he concludes that "in Man the cause of eruption, or at least an active factor in producing eruption, is to be found in the disproportionate growth occurring in the tissues forming the tooth and the tissues surrounding the tooth."

Strong objection may with reason be taken to this theory, for the operations in the group of fishes—particularly the lowest type of fish—are so dissimilar to those of the higher mammals, that comparisons and deductions are superfluous, and offer an interesting example of paralogism. The *Chondropterygyii* and the *Primates* cannot be thus approximated—they are far too widely separated in the scheme of Nature.

"Epiblastic" Theory.—It is hardly necessary to mention that some have considered that enamel, being epiblastic in origin, should, like other dermal tissues, have an inherent tendency to "come to the surface." The absurdity of this tenet is at once apparent, for the teeth of some of the *Edentata* which possess no enamel, erupt—while occasionally odontomes composed entirely of dentine or cementum also seem to undergo the same process.

Addition of Dentine.—The addition of dentine to the extremities of the roots has been referred to by Norman Broomell.[1] He too realizes

the difficulties of explanation, for he writes: "In a general way the advancement of the crown may be said to result from the elongation of the root by the addition of dentine to its free extremity. But when it is taken into consideration that the cuspid teeth, both deciduous and permanent, have their roots fully or nearly calcified before they begin to advance towards the surface, an exception to the generally accepted theory is established."

Influence of Nutrition.—The influence of nutrition is believed by Sayre Marshall[12] to have some effect upon the erupting crowns. Some change occurs in the gums and in the walls of the dental crypts. There is possibly a withdrawal of a certain amount of the blood supply of the neighbouring parts through great activity in the growth of the dental follicle "just preceding and during the period covered by the process of the extension of the crown. This is one aspect of the belief in the physiological processes of growth which appears to the author to be the only tenable theory at present worthy of acceptance."

THE TIMES OF ERUPTION

There is a great divergency of opinion regarding the dates of eruption both of the deciduous and of the permanent dentition. The reasons are quite obvious; systematic attempts have been rarely conducted, and published tables have been copied from text-book to text-book.

An admirable example of the method of *déduction en circle* may be mentioned in the fact that some writers have given statistical information of eruptive dates from the examination of collections of crania in Anatomical Museums. The rate of progress or stage of the phenomena is noted in skulls of certain age; therefore, that represents the conditions at that stage.

It may be easily forgotten, however, that the age of the skulls has been probably empirically founded upon the state of eruption. The age of the skulls themselves is guessed by the amount of growth of the teeth, and the phases of eruption, and the dates of eruption are governed by the supposed age of the skulls. Another fallacy also exists, and that is, probably, a large proportion of these crania which find their way into Museums are from diseased persons—rickety and

syphilitic; and hence, from the point of view of time, are perfectly unreliable.

The real truth cannot be attained until a body of dental surgeons who are parents, and who are willing carefully to note the actual dates of the observed eruption of the various teeth in the mouths of their children, will determine to collect statistics in this important matter.

Meanwhile a step in the proper direction has been made, as already mentioned, by Mr. Warwick James,[9] who has recently published a list of approximate dates of the eruption of the permanent teeth of 4850 children below the age of twelve years. They were certainly attending as patients at a Children's Hospital, but it is probable that these computations are those of children free from any disease which would affect the growth and eruption of their teeth.

The following list comprehensively shows at a glance the table of dates given by several eminent anatomists and observers.

Order of the eruption of the teeth.	Dates of eruption. Quain.	Zuckerkandl.	Magitot.	Debierre and Pravaz.	James and Pitts. Yr.	Mth.
A *Deciduous Dentition.*						
First mandibular incisor	7th to 9th month	6th to 8th month	7th month	7th to 8th month		
First maxillary incisor			10th month	10th month		
Second mandibular incisor	Some months after	8th to 12th mth.	16th month	12th to 14th month		
Second maxillary incisor		....	20th month	15th month		
First mandibular molar	4 or 5 months later	12th to 16th mth.	24th month	15th to 18th month		
First maxillary molar		....	26th month	18th to 20th month		
Second mandibular molar	About 24th month	20th to 30th mth.	28th month	24th month		
Second maxillary molar			30th month			
Mandibular canine		15th to 20th mth.	.... 30th to 33d month	24th month		
Maxillary canine						
B *Permanent Dentition.*					Yr.	Mth.
First mandibular molar	6th year	6th to 7th year	5th to 6th year	....	6	6
First maxillary molar			5th to 6th year	....	6	6
First mandibular incisor	7th year	7th to 8th year	7th year	....	6	6
First maxillary incisor			7th year	....	7	9
Second mandibular incisor	8th year	8th to 9th year	8th year and 6th month	....	7	6
Second maxillary incisor				....	9	3
First mandibular premolar	9th year	9th to 11th year	9th to 12th year	....	9	9
First maxillary premolar				....	9	3
Second mandibular premolar	10th year	11th to 13th year	11th year	....	10	6
Second maxillary premolar				....	10	3
Mandibular canine	11th to 12th year	11th to 13th year	11th to 12th year	....	10	6
Maxillary canine				....	11	9
Second molars	12th to 13th year	13th to 15th year	12th to 13th year	....	11	9
Third molars	17th to 25th year	17th to 40th year	19th to 25th year			

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CHAPTER XV

THE FUNCTIONS OF THE DENTAL TISSUES

Introductory.—The Uses of Nasmyth's Membrane.—Of the Enamel.—Of the Dentine.—Of the Dental Pulp.—Of the Periodontal Membrane and Cementum.—Of the Gum.—The Sensitiveness of Teeth.—Of the Enamel.—Of the Dentine.—Of the Cementum.—Dental Pain.—Modifications of Sensation.

Introductory.—A tooth—and by this is implied a human tooth—consists of three calcified tissues—enamel, dentine, and cementum—all extremely hard in character, but each essentially different, chemically, physically, physiologically (functionally), and histologically. It might have been supposed that Nature in order to supply the needs of speech, mastication, and adornment would have provided bodies similar in many respects; would have manufactured a tooth of one material only, and paid no attention to minute details in the way she has done. For not only is a tooth functional as a whole, but every portion of it has its uses, and when abused or disused, suffers directly, and produces indirectly diseases or defects in the dental organism.

This chapter seeks to give an account of the uses of these various parts, and, taking into consideration the teeth of fishes, reptiles, and the lower animals, to prove that in a human tooth there is the highest embodiment of all the functions which the dental organs are called upon to perform. One need not here discuss the physiological values of the various dentitions amongst the Vertebrates. Attention may, however, be given to a description of the particulars of the several offices of the hard and soft parts of teeth, taking as a type the teeth of Man.

THE USES OF THE DENTAL TISSUES

Nasmyth's Membrane.—The precise *rôle* that Nasmyth's membrane plays with regard to the enamel is at present but little under-

stood. Professor Paul,[7] in 1894, published an article which described the real nature of the membrane, and there hinted that its function was probably a protective one. He says: "It seems reasonable to suppose that enamel devoid of its protection could hardly compete with that which is shielded by it," and asks: "May it not protect the enamel from those chemical changes constantly at work in the mouth?"

A study of the histology and physiology of Nasmyth's membrane has been much neglected. Writers on dental caries give careful patho-histological descriptions of the enamel and the dentine, but some have invariably ignored the presence of the enamel cuticle, and it is just possible that the bacterial plaques of Black and Miller may be merely remnants of this acid-resisting tissue. Whether it exists or not, and if so, what are its functions in the teeth of certain *ungulata*, where enamel is covered partially or completely by cementum, are, as yet, undecided points. The writer has, in nearly every human tooth which he has decalcified—in carious as well as sound normal examples, even in teeth of patients over seventy years of age—found strips of the membrane which have clung most pertinaciously to the free surface of the enamel. He is, therefore, inclined to place great importance on the presence of the tissue. Its position on the circumference of the exposed portions of the teeth, its keratinous character, its resistance to acids and alkaline solutions, its comparative toughness, all intrinsically act as a defence to the underlying parts. If it were possible that mechanical abrasion or attrition could have no effect upon any portion of it—these two forces are, of course, absent in the region of natural pits and fissures—dental caries would be a thing unheard of and dental disease its offspring unknown. The weakness of Nasmyth's membrane unfortunately lies in its extreme tenuity and inability to withstand the shocks of friction or traumatism, with the result that its presence may possibly really act as a menace when torn, microörganisms finding a nidus for development at its ragged margins.

The Enamel.—It is patent to every reader that the main office of enamel is to form a hardened case for the body of the tooth proper, as an instrument for dividing, comminuting, and triturating food,

and as a mechanical protector to the adjacent dentine. One would expect that, for these properties, the patterns of all animals would be universally similar. All that could possibly be needed would be a calcified substance, dense, strong, enduring, non-frangible, which would act like a chisel, or a mill, or a grindstone. On second thoughts, however, it is recalled that the diet of animals, fishes, and reptiles is enormously diversified, and then one begins to remember the manifold types of dentition, such as the carnivorous, the herbivorous, the insectivorous, the omnivorous, etc. Here is found an explanation of the fact that, according to the requirements of the creature, so has Nature modelled the jaws, and the shapes, sizes, positions, and numbers, as well as the structure of the teeth, and has adaptively modified even the enamel for the varying degrees in hardness or softness of the food.

But the beneficent agencies of Nature have been further extended, and a beautiful adaptation of means to an end is seen on the microscopical examination of various enamels.

In Fishes the simplest type of conformation is noticed. A plain, structureless, minute cap of enamel serves the purpose of covering the dentine, as, exemplified, *Merlucius vulgaris* (the hake), *Anguilla acutirostris* (the eel).

In the *Mammalia*, on the other hand, the most complicated patterns imaginable are found amongst the rodents—the squirrel, the beaver, etc.—where the arrangement of the enamel rods is wonderfully appropriate for the extreme kind of work which the teeth have to undertake, in the gnawing of the bark of trees, the cracking of the shells of nuts, and so on. Amongst the lower animals many interesting and suggestive and surprising facts come to light. Thus, the *Orycteropus capensi* (the Aard-vark or ant bear), of the Ethiopian regions of the world, has no enamel, simply because its food, being largely of termites, hard-crushing organs in the mouth would be out of place.

Again, the *Manatus* (sea-cow), which inhabits the coast of the warm parts of the Atlantic, the Bay of Bengal, the Australian seas, has eleven pairs of cheek teeth in maxillæ and mandible, subsists on seaweeds and aquatic plants, which it masticates like a pig, and has the enamel rods running simply in straight lines, a weak sort of structure

perfectly adapted to the tearing part of the leaves and stems of aquatic plants.

The *Halicore dugong* (dugong), which is also found in the Red Sea, off the coasts of India and Malay, and Australia, being entirely marine, and not fluviatile in its habits like the Manatee, eats the still softer sea-weeds of these waters, and does not even require an enamel casing to its cheek teeth.

Instances need not be multiplied. Suffice to say that the greater the work the enamel has to do, the more complicated the pattern. So in the molars of Man, the flexuous courses of the enamel rods give rise to a very complex pattern, showing great strength and rigidity; but even these enamels are not so intricate in style as the incisors of the porcupine and other rodents, while they are more so than the incisors and canines of Man.

The enamel of the Marsupials is tubular. The real reason of this tubularity is unknown. It probably represents an imperfected condition, an example of atavism.

The Dentine.—The functions of dentine are not difficult to define. To give substance to the tooth itself, to provide a centre of sensation, to protect the pulp, are its manifest uses. Enamel is without the pale of nutrition, the pulp is highly vitalized, and the dentine is on the borderland of the living and the dead—semi-vitalized, if one may so speak. Nature would not for an instant tolerate the presence, in the midst of living tissues, of a dead body like the enamel. The result is, therefore, the presence, between the living pulp and the inert enamel, of a large area, relatively speaking, of a tissue which is marvellous and unique.

In no other part of the body do we find an entirely tubular structure like dentine. Its peripheral parts, where it joins the inorganic enamel, are less vitalized than its central parts. This explains the reason why the dentinal tubules are not of the same calibre throughout their lengths. The contents of the tubes is protoplasm, which is more abundant at the pulp end than at the enamel end. Nature would have made a mistake had she made the tubules of the same diameter throughout. "In width"—the writer quotes from his "The Histology and Patho-histology of the Teeth and Associated Parts,"[3] "they

vary from 1.7μ to 2.2μ or 5μ (Kölliker); 2.5μ (Owen); or 0.0055 mm. . . . The diameter of the tubes diminishes as it proceeds outwards, till at the peripheral region of the tooth it becomes immeasurable."

The dentine of the crowns of teeth is more plentifully supplied with living material (protoplasm) than the roots; hence, the tubes branch more frequently in the latter than in the former situation. The writer believes that a serous exudation fills the tubes, bathing the dentinal fibrils—that is, the peripheral poles of the odontoblasts—and, according to Howard Mummery, the dentinal nerves, and that this exudation is nothing more nor less than the living protoplasm extruded from the trophic pulp. He is unable at present to offer any explanation as to the utility of a vascular dentine like the vaso-dentine of *Merlucius*, the osteo-dentine of *Esox lucius*, and the folded dentine of the *Lepidosteus* or *Varanus niloticus*.

The Dental Pulp.—Of all the tissues of a tooth the pulp is not only the most sentient, but the most vitalized. On the life of the pulp depends the existence and welfare of the tooth. The bloodvessels carry to and remove the waste products of the life-giving properties of the pulp; the nerves serve a twofold purpose, a sentient one to act as sentinels in case of danger, and to act also as regulators of the blood traffic. They govern the blood supply very largely; and through their nutrient influences give tone to the arteries, veins, and capillaries. As a whole, the pulp affords a very remarkable physiological resistance to disease. In cases of pathological absorption of cementum and dentine it is often still encased by an area of dentine, withstanding to the last the encroachments of the morbid conditions which produce the rarefying periostitis. Then, again, in cases of breach of surface of enamel or dentine, the pulp quickly responds by depositing adventitious or secondary dentine on its surface in threatened caries or erosion or attrition.

The odontoblasts probably serve three distinct functions: (1) The transmission of nervous stimuli to the pulp; (2) the regulation of the intensity of the stimuli; and (3) a trophic control over the protoplasm in the dental tubes. They are in no sense nerves themselves. It would be difficult to believe that a non-medullated or even a medullated nerve fibre could exist *per se* in a bony tube or canal.

There is no doubt whatever that the dentinal fibrils are part and parcel of the odontoblasts, and it is highly probable that the latter act as sensation transmitters, intervening between the terminal arborizations of the sensory pulp nerves on the one side, and the lifeless enamel and semi-vitalized dentine on the other. They do not form dentine matrix.[3]

They differ in size in different parts of the pulp; they are not concerned with the formation of pulp nodules; and they possess a more important function than that of merely keeping the dentinal tubules patent. The main argument that has been advanced that the odontoblasts cannot be associated with the nervous mechanism of the teeth, on account of their embryological factors, would appear to be losing ground. Derived from the mesoblast of the dentinal papilla, and not from the epiblast it has been repeatedly argued that, therefore, they cannot play the *rôle* of sensation transmitters to the dentine, or be at all analogous or homologous with the nerve ganglia or end organs of the general peripheral nervous system. But botanists, zoölogists, and biologists are beginning to discover fallacies in the "Gastrœia Theorie" of Haeckel,[2] who definitely laid down the axiom that the nervous system is derived from cells of epiblastic origin. It is now found that all strict homologies based on this three-germ layer are very doubtful. The three-germ layers—Dermatogen, Periblem, and Plerome—of the botanists are now practically discarded, although previously held to as rigidly as even McBride holds to the three-animal layers. Von Klaatsch has stated that the mesodermal cells which give rise to bone are really epiblastic cells which have wandered deeply. The evolution of the clavicle shows the possibility of an original epiblastic origin. That there is really no hard and fast separation between epi- and hypoblast is evidenced by the development of some of the sponges, and many of the facts of regeneration. The interested reader may refer to "The Nervous System" by Barker,[1] and the still more recent writing of Korschelt and K. Heider.[4] The facts that they not only submit, but emphatically insist on, are indisputable and absolutely irreconcilable with the requirements of the old-fashioned germ layer theory.[5] Thus they have incontrovertibly proved that in the invertebrate moss-animals (*Polyzoa* or *Bryozoa* which form

Sub-kingdom VI, intervening between the starfishes and the worms, of the animal kingdom) the whole of the alimentary tract is of ectodermal origin, in the Planarian worms the nervous system and the pharynx are mesodermal. Among the Vertebrates in Class VII (*Protochorda*) containing lower forms of life than the lamprey and hag fish are certain small very lowly organized marine animals, the sea squirts and lancelets. Closely related to *Amphioxus* are *Botryllus*, *Salps*, *Pyrosoma*, *Doliolum Tritonis* amongst others. Of these the nervous system of the first is ectodermal, of the others mesodermal. The sea squirts present a nervous system which emanates from the endodermal cells.

These observations coming from such authorities should *donner a penser a quelqu'un:* the present day critic cannot possibly ignore them.

The Periodontal Membrane.—It is a task of no little difficulty to ascertain precisely the real physiological properties of the periodontal membrane. One knows so little of its structure; it is veritably a *terra incognita*.

Pending further and fuller information, however, it may be said that its functions are physical, sensory, nutrient, and formative.

A (*i*) It acts as an apparatus for diminishing the force of concussion with an opposing body, whether it be dental or otherwise. (*ii*) It affords a fibrous attachment to the teeth, Malassez, in 1885, comparing it to a ligament. (*iii*) It provides a layer of soft material in which bloodvessels and nerve fasciculi to supply the teeth may ramify without risk of damage or permanent and inoperable injury by mechanical shock. Through its venous supply it becomes (B) sensory, an important function in that it is capable of detecting pain, a beneficial arrangement on the part of Nature. (C) Like the periosteum of other bones it possesses a certain degree of trophic influence on the alveolar walls of the dental sockets, and (D), it is formative in that it is capable of very frequently providing, by virtue of its osteoblasts, fresh tissue (hyperplasic cementum) on its inner aspects, which is an evidence of its reaction to injury of a traumatic, chemical, or bacteriological character.

The Cementum.—As far as cementum is concerned, the author believes that it, too, like enamel, is devoid of life; that normally the lacunæ with their containing corpuscles are absent; that when they

do appear, they are symptomatic of a previous inflammation of the periodontal membrane, or some form of irritation of that tissue, which induces a hyperplasia, on account of the revived activity of the osteoblasts in the membrane. The inference, therefore, is that human cementum serves as a sort of dense, non-sensitive, inert covering for the dentine of the roots of teeth, being analogous to and homologous with the peripheric lamellæ of compact bone. The proof of this statement has not yet been worked out, but the writer hopes some day to put on record his observations on this subject. Meanwhile, he entirely disagrees with Tomes,[9] who says "The human tooth is connected with the living organism very intimately, even though its special tissues are extra-vascular. For blood vessels and nerves enter the tooth pulp in abundance; the dentine is organically connected with the pulp by the dentinal fibrils; these are connected with the soft cement corpuscles, which again are brought by their processes into intimate relationship with similar bodies in the highly vascular periosteum. So that, between pulp inside and periosteum outside there is a continuous chain of living plasm."

In the molars of the horse, and some ruminants, it serves to maintain a rough uneven surface to the crowns, for the purpose of the thorough comminution of food; and in the elephant, it binds together the plates of enamel and dentine which form the component parts of the molars.

The Gum.—On account of its smooth surface the gum acts as a protective covering to the alveolar processes of the jaws, to the periosteum of which it is also nutritive through its abundant blood supply. It fills up the triangular interdental spaces, which largely prevents the lodgement of food in these situations. By means of its mucous glands it probably has some share in the general lubrication of the mouth. It furnishes a set of blood vessels to the periodontal membrane. In certain *Ungulata* it provides a biting pad against which the mandibular incisors are applied.

From what has been said it is clear that, even in elementary subjects such as have been hurriedly sketched above, there is much yet to learn; and it is only by studying Comparative Anatomy, by examining the histology and embryology of parts, and by correlating the ascer-

tained facts and theories of dental pathology and clinical experience with them, that one can hope to arrive at satisfactory and scientific conclusions which would be of permanent value to the dental profession.

THE SENSITIVENESS OF TEETH

Enamel.—The sensitiveness of teeth is a normal physiological condition. As far as is at present known, enamel itself is not innervated. Its physical properties are such as to prevent it from generating sensations of any kind. There are no nerve endings in enamel. Morgenstern and Römer believe that nerve end organs can be found in

FIG. 297

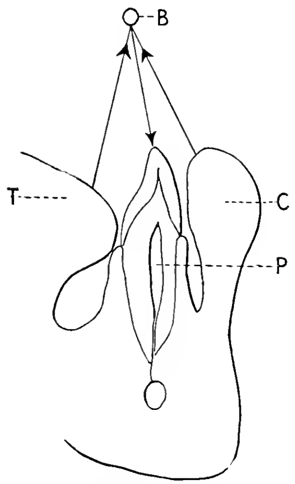

Diagram of a reflex act. The sensory nerves in (*T*) the tongue and (*C*) cheek send stimuli to (*B*) the brain, which transmits them to (*P*) the dental pulp. Thus exceedingly sweet substances on the tongue will, at times, produce odontalgia.

FIG. 298

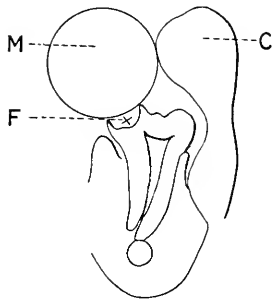

Diagram of a reflex act. An electrical impulse may set up momentary odontalgia when two dissimilar metals, such as those of the edge of a hand mirror (*M*) and (*F*) of a metallic filling, meet, and the circuit is completed by (*C*) the mucous membrane of the cheek, the saliva acting as the electrolyte.

the enamel spindles which exist at the amelo-dentinal junction, but are variable in number, shape, and size. These views, however, are not generally held, and indeed there are many insuperable difficulties connected with the theory—objections of histogenesis, of phylogeny, of reason. Enamel perhaps may mechanically transmit impulses to the pulp by shock, but it is incapable *per se* of initiating them.

It is a remarkable fact that the physiological phenomena set up when substances of various kinds, taken into the mouth, are brought into direct contact with the teeth cannot precisely be described. This sensitiveness is extraordinary, distinguishing, accurately and immediately, between the shapes, proportions, and constitutions of wholly dissimilar foreign bodies such as shot in game, a crumb of bread, a delicate hair, a piece of thread—silk or otherwise—a fragment of gritty sand, or particle of comminuted food—a sensitiveness which causes its rejection or retention—a sensitiveness, too, of degree, whereby differences are at once detected between the comparative softness of a small leaden bullet, and the dense hardness of a piece of shell. It is extremely probable that the sensory nerves distributed to the cheek and the tongue materially assist the perception of the minute tactile impressions made upon the enamel, and produce a complete series of sensations at present entirely inexplicable. As long as no breach of surface occurs this sensation is one of touch or discomfort, not one of pain.

Dentine.—Certain molecular movements occurring externally cause a distinct perception or group of perceptions on the part of the pulp, with its prolongations in the dentinal tubes, which converts these movements into nerve impulses, that immediately pass by an afferent channel to the brain. The dentine, and through it the pulp, acts like a sense organ: when exposed, the periodontal membrane acts, too, like a sense organ in a different way, and is of a different character to that of the pulp. Müller's law of specific irritability can be applied to the dentine (*i. e.*, the pulp) just as well as to the optic or the auditory nerve. It states that every sensory nerve reacts to one form of stimulus, and gives rise to one form of sensation only. Thus chemical, mechanical, thermal, electrical,* and other sensigenous impressions produce only one subjective effect—pain. Nor does the intensity of this result depend, as in other parts, upon the strength of the stimulus; in the tooth this proportionately breaks down, and Weber's law or Fechner's—"The increase of stimulus which is required to produce distinct increase of sensation always bears the same ratio to the whole stimulus"

* See Appendix—Note C.

—fails, even though the stimulus be of the slightest. Pain is not merely an exaggerated tactile or temperature sensation. In cases where a tactile sense is deficient, the pain sense may be exalted. It is well defined, and regulated by a distinct set of nerve fibres. The dentine, like the cornea, perceives only painful impressions; it cannot discriminate between tactile or thermal sensations.

Dentinal sensibility, to repeat, is a normal physiological condition. In Man it reaches its highest degree of development. If dentine were not sensitive, frightful havoc would probably be worked by the micro-organisms which produce dental caries in the mouth; every tooth would universally "decay," and be promptly rendered functionless and a source of danger to the body generally. Such organs would never be required. Scalding hot fluids might be taken into the mouth with impunity, with obviously disastrous effects. The sensitiveness of dentine is Nature's protection to the teeth and to the oral tissues.

As fishes and reptiles have no caries-producing microörganisms in their mouth, sensitive dentine is not wanted. Hence many piscine dentitions are entirely tubeless and therefore sensationless. In Mammals, and particularly the lower Mammals *in naturâ ferâ*, it is possible also that dentine is practically insensitive. But in Man the abundant distribution of the sensory nerve fibres in the pulp is quite remarkable, much more than is needed for the mere purpose of acting as trophic agents for that organ. This question of pain in the teeth is very complex, because it may be partly conveyed—in a mechanical sense—by the matrix of the dentine, as well as by the contents of the dentinal tubes. Of the latter we know but little, of the former nothing.

In section the dentine presents innumerable channels which become smaller as they pass centrifugally outwards. There are probably no nerves, neither medullated nor non-medullated in dentine.* The

* Since this was written, Mr. Howard Mummery, whose researches on the calcification of dentine are well known, has communicated to the Royal Society a paper dealing with the innervation of human dentine. By the use of various metallic impregnation stains, notably those of Ramon y Cajal, he has demonstrated the presence of delicate beads or dots in the dentinal tubules. As yet, however, the paper has not been published; suffice to say that he is of the opinion that the medullated nerve fibres of the pulp lose their medullary sheaths as they approach the plexus of Raschkow, whence they pass between and around the odontoblasts to a narrow marginal plexus from which they enter the dentinal tubes, and, accompanying the dentinal processes of the odontoblasts, extend outwards to the extremities of the tubes, beneath the enamel and cementum.

tubules are filled during life with a protoplasmic exudation from the pulp, which bathes the peripheral processes of the odontoblasts on its surface.

Many theorists and physiologists differ in their views as to the actual causation of sensation. Thus some maintain that osmosis occurs in the dentinal tubules, that drugs can produce it. Water is abstracted or added to the contents of the tubules, as by the action of alcohol or sugary compounds, and pain results. Others, the hylopathists, consider that abnormal movements in the molecules of the dentinal fibrils may occasion it. Others, that an elevation or a lowering of the pressure in the pulp cavity itself will evidence it. Others, again, that convection may take place in these fibrils as on the application of a stream of heated air; and finally others, that certain obscure electrical reflexes, similar to the demarcation currents observed during injury to a muscle, may produce it. It is difficult to determine the truth; and at present it is impossible to make a clear specific statement on the matter, unless and until Howard Mummary's observations are fully accepted.

It would probably be true, however—it remains for future observations to determine—that the nervous perceptions of a tooth are so high and so complex from a physiological point of view, that the pulp may be considered to be a very special sense organ, ranking, not equally, but in some considerable degree or manner, with those of the special senses of hearing, of sight, and of taste themselves. Moreover, it must not be forgotten that a tooth is essentially a unique structure, having in its interior a highly sentient body, and on its periphery an inert, dead, irresponsive material with an intermediate region of semivitalized, semiperceptive tissue, of which the like exists in no other portion of the human economy. Microscopically, it is probable that nothing occupies a dentinal tube except lymph and the dentinal fibril, which usually on account of reagents, has shrunk to or near its axial parts. As this is protoplasmic in character and nervous in function, and is part of an odontoblast, it follows, if these premises are correct, that the syllogism is completed by concluding that the odontoblast is a sensation transmitter, and an end organ of the non-medullated nerve fibres of the pulp, its fibril or fibrils—for there may be more than one

from one cell—the dendron or dendrons and its ultimate branchings, the dendrites.

Cementum.—It has been frequently asserted that cementum is sensitive. It is probable that this is an erroneous belief. This tissue does not require a nervous supply, and nothing in the shape of nerves have ever been demonstrated in its substance. It is very thin and is, normally, practically structureless, the amount of its protoplasmic content being almost a negligible quantity. The hypothesis of sensitiveness in cementum probably arose from the fact that, when exposed by absorption of bone, the roots of teeth—*e. g.*, the palatine roots of the maxillary first and second molars—may at times have painful sensations relegated to them. It is more than likely that this is due either to transmission of sensations through it to the radicular pulp, in an analogous manner to that which obtains in the enamel, or to exposure of the free margin of the periodontal membrane which has become diseased; or it may be a combination of the two.

Not only is a tooth anatomically and physiologically a unique organ, but the suffering it experiences through exposure of its dentine by caries, or as a consequence of the effects of a vascular legion of the pulp, is also unique. It is a common clinical experience to find a cavity of "decay" well advanced before any symptoms of pain (odontalgia) have exhibited themselves. On the other hand, the reverse may often be met with.

In the same individual two or more types of pain-emitting phenomena may occur simultaneously. Attention may be directed, because of the discomfort which is experienced, to a deep cavity in which a filling has become shrunken or loosened, and, close by, or in another region of the mouth, there may be a similarly deep excavation of the hard tissues, of which the individual knows nothing. What physiological and pathological processes are at work in these circumstances? Who can explain these conditions?

Recent investigations in the physiology of the nervous system of the body generally, and particularly of the sensory nerves, would tend to show that the method of conveyance of sensations to the brain by the ordinary routes is not so simple as has hitherto been believed. Professors Sherrington and Head have demonstrated that both the motor

and the sensory nerves act in a somewhat complex fashion. The old theory held that if a series of definite impulses was applied to certain parts of the body, the sensory nerves conducted the impressions to the brain, where they were either made known to the mind of the individual only, or were immediately responded to by the motor nerves. Thus, if the hand is plunged into warm water, a sensation of pleasurable warmth is experienced, or if the water be too hot the hand is at once withdrawn on account of the painful impressions made upon the sensorium.

But it has been found that, though sensations do travel to the brain, they do not all journey at the same rate. In other words, they probably race one another, and that sensation which reaches the cerebral convolutions first, shuts out the others from competition, so to speak, in much the same way as a horse which has won a race. The sensations which start from the periphery when the hand is placed in pleasurably warm water are of various kinds, and the sense of pleasant warmth is that one which reaches the brain first. By means of a suitably contrived apparatus it is possible to prevent this sensation winning the race, and if used in appropriate conditions, when the hand is plunged into pleasurably warm water, the first impulses which reach the brain are those which give rise to the sensation, not of warmth, but of pain!

The hypothesis which can be based upon this experiment would lead one to believe that the evolution of the sensory nerves in the human organism has continually been in the direction of the avoidance of giving the human being pain. The nervous system has been compared to a "bankrupt telephone exchange," in which nerve and sensation are hardly ever related, the seat of pain, and its cause, being united by a bewildering system of so-called "way-leaves." Some of the abdominal viscera, such as the liver or pancreas, possess a nervous mechanism which evolution has rendered insensitive; the result being that the existence of an injury of one of these organs has to be diagnosed, not from the direct pain in the parts, but by totally different subjective and objective symptoms. Physiological telephoning, unlike the real thing, is hardly ever direct; communications have to be made in all sorts of round-about ways.

It may be possible that herein lies the explanation of the existence of the sensation of discomfort which is constantly perceived by the teeth, as distinct from the usual pain of a neuralgic character.

DENTAL PAIN

The dentine is said to have an area—presumably that occupied by the interglobular spaces—near its surface peculiarly liable to set up symptoms of pain. Dental pain is without a like or equal, and differs from that elsewhere. If a decapitated frog should have an irritant applied to the skin of its leg—a well-known experiment—it will, though unable to become aware of pain, at once retract that extremity and endeavour to get rid of the source of offence, a proof of the existence, here, of a reflex mechanism which resides over the nerve supply of that part. Now pain was evolved for the benefit of the organism which perceives it. Pain is, in its origin, a magnificent protection. But in the teeth there are no evidences of definite and direct reflex arrangements being made by Nature for the removal of irritants without any association with sensation, as in the frog for instance, or elsewhere, such as the cornea, the skin, etc. The beneficence of pain in the teeth is, therefore, very slight; in other parts of the body it is very great. If pain did not exist, the teeth would share the same fate that other organs would undergo under similar conditions, and would be rapidly destroyed; but, as its protective influence is a modified one—it is frequently hypalgesic—many cases occur where destruction goes on without its making itself felt. A reflex act is not required here, and is non-existent. In the teeth it would appear that pain is an epiphenomenon, and not causally related to the conditions that naturally obtain in other regions.

Fully aware that the above views are widely divergent from those commonly held, the author has set them down nevertheless, in the earnest belief that, while open to modification, they are, in the main, correct.

The sensitiveness of the teeth diminishes with advancing age. For anatomical reasons it is naturally more acute in the young. Exposure

of the pulp in the aged is practically unattended by symptoms of severe if any pain. The cause is plain and not far to seek. If the apical regions of any tooth removed from the mouth of a middle-aged person be examined, it will commonly be observed that the apical foramina, which transmit the afferent arteries and nerves and the afferent veins, is almost invisible. They have in the course of time become extended. Normal closure of the apices—that is the physiological cessation of growth of the extremities of the roots occurs—as far as can be at present ascertained—as follow:

Maxillary Series: First incisor, twelfth year, second incisor twelfth year, canine fourteenth year, first premolar thirteenth year, second premolar thirteenth year, first molar twelfth year, second molar seventeenth year, third molar nineteenth to twenty-fifth year.

Mandibular Series: First incisor eleventh year, second incisor twelfth year, canine fourteenth year, first premolar thirteenth year, second premolar thirteenth year, first molar eleventh year, second molar eighteenth year, third molar twenty-first year to twenty-fifth year. But after the age of thirty years these open canals become generally less patent, until at and above fifty—to make a shrewd conjecture—the pulps, cut off from their usual trophic supply, are degenerated and presence of pain slowly modified and diminished. It is extremely probable that after the age of thirty-five the teeth of the ordinary European, American or Asiatic individual possess degenerated and only slightly sentient pulps.

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CHAPTER XVI

MAMMALIAN DENTITIONS

The General and Dental Characteristics and Variations of the Teeth of the *Cheiroptera*.—Of the *Insectivora*.—Of the *Rodentia*.—Of the *Carnivora*.—Of the *Cetacea*.—Of the *Sirenia*.—Of the *Ungulata*.—Of the *Edentata*.—Of the *Marsupialia*.—Of the *Monotremata*.

Sub-Class II. Eutheria (continued)

ORDER XII. CHEIROPTERA

Placed high up in the scale of mammalian development, are the flying mammals, known as the Bats (Cheiroptera: Χεὶρ, hand; πτερὸν, wing), creatures which are more specialized even than the numerous carnivorous species of animals.

The Bats are flying vertebrates, having as wings a thin integumental membrane which intervenes between the hind limbs and tail, and the digits of the fore limbs. The radius is curved and long, the ulna elementary. The membrane is provided with vascular and nervous systems, and lies chiefly between the second and fifth digits, which are enormously long. The mammæ are thoracic, and the smooth cerebral hemispheres do not extend over the cerebellum. (Bedhard.)

The order is divisible into two primary groups, of which each is further subdivided. These are known as:

Sub-order I. *Megachiroptera* (μέγας, great—Χεὶρ, πτερὸν), of which the most important Family is the *Pteropodiæ*.

Sub-order II. *Microchiroptera* (μικρός, small), which includes:

Rhinolophidæ
Nycteridæ
Vespertilionidæ
Emballonuridæ
Phyllostomatidæ

Of these the *Megachiroptera* are frugivorous bats, of large size, and the *Microchiroptera* are mostly insectivorous, but in some species frugivorous and sanguinivorous.

Comprised in the former is the *Pteropus* (Fox-bat). There are about sixty species. It is commonly found in India, Madagascar, Australia, Queensland, etc.

FIG. 299

Skull of a frugivorous bat (*Pteropus fuscus*). $\times \frac{9}{10}$.

Dental Characteristics.—The incisors are small, the molars large, with intervals between, and not tubercular, but divided by a longitudinal ridge. The teeth are haplodont, and flattened from side to side.

The *Microchiroptera* include four hundred species, and are distinguished by the presence of "nose-leaves" which act as tactile organs. In this group are placed the False Vampires, the Horseshoe bats, the White bat, the Vampire, or blood-sucking bat (*Desmodus*), which is capable of sustaining its life by gorging the blood of man and animals. Its œsophagus is too narrow to allow more than a fluid diet to pass.

NORMAL TYPE.—The incisors are small, the canines large, the premolars and molars possess sharp cusps, and present a W-shaped pattern of their ridges.

ABERRANT TYPE.—*Desmodus*, the Common Vampire, has a large, permanent upper incisor, which is prismatic in form, in each jaw. The canine, smaller than the preceding, is sharp, and pointed and large. The molars are stunted in growth, and differ but slightly in their configuration from the premolars.

ORDER XI. INSECTIVORA. (*Insecta*—insects, *vorare*—to devour.)

Sub-order	Family	
(i) *Dermoptera*	*Galeopithecidæ*	(Flying Lemurs)
(ii) *Insectivora vera*	*Erinaceidæ*	(Hedgehogs)
	Tupaiidæ	(Tree-shrews)
	Cantetidæ	(Tenrecs)
	Potamogalidæ	(Potamogales)
	Solenodontidæ	(Solemodons, fish-eaters as well as insectivorous)
	Chrysochloirdæ	(Golden moles)
	Macroscelidæ	(Jumping shrews)
	Talpidæ	(Moles)
	Soricidæ	(Shrews)

In geographical distribution insect-eating mammals are found in North America and the Old World. They are absent from the continents of Australia, South America, and the Islands of Japan. In South America the Marsupial opossum corresponds to this order.

The *Insectivora* are all small vertebrates, the great majority being nocturnal in habit, and their ancestry very ancient, suppression of some of the deciduous teeth pointing to this. The limbs usually possess five digits. Clavicles are present as a rule. The dental characteristics are fairly regular, the typical mammalian dentition being very common. Most cheek teeth are trituberculate, again indicating the antiquity of the group.

General Dental Characteristics.—Normal Type.—There are never less than four mandibular incisors in any of the species, the first incisors are often larger than the second, the canines are usually smaller than the former, no "carnassial" tooth is present, and the crowns of the molars are surmounted by a number of cusps which are arranged in V-shaped ridges in the Golden Mole,[5] W-shaped ridges in the Mole, and themselves are triangular and tricuspid in pattern in the first-named and quadrangular in the hedgehogs, moles, and shrews. The dentition is diphyodont, and the teeth are heterodont.[20]

Aberrant Type.—The controversial nature of the dental formula of the Mole[2] has already been alluded to. Its eyes are rudimentary. It eats insects and earthworms. It is calculated that one mole can eat, independently of other food, 20,000 earthworms in a year, and hence, like many of the *insectivora*, is exceedingly voracious. If kept without food, or unable to obtain it for a period of twenty-four hours, it dies of hunger. It adopts in extreme cases of exhaustion a curious subterfuge, and is said actually to catch birds, by burying itself in a mole-hill, and moving its muzzle continuously to and fro, just beneath the surface, to attract any incautious bird which may be deceived by thinking that it is an earthworm that is stirring.

The *Shrews* have tubular enamel, which is also greatly pigmented. On the authority of Sir W. Flower, adult shrews exhibit the unusual condition of anchylosis of their incisors to the bones of the jaw. Vestigial remains have been discovered in association with these teeth.

The *Galeopithecus volans* has pectinate incisors. Its dental formula according to Leche, is I $\frac{2}{3}$ C $\frac{0}{0}$ Pm $\frac{3}{3}$ M $\frac{3}{3}$ $\times$ 2 = 34.

The second incisor is bi-rooted.

ORDER X. TILLODONTIA (τίλλω—to tear; ὀδούς—tooth)

Extinct rodents.

ORDER IX. RODENTIA (*Rodere*—to gnaw)

The rodents comprise nearly a thousand known species. In distribution they are cosmopolitan, most chiefly located in South America, while Australia has but few genera. All are exclusively herbivorous, and obtain their food by gnawing. While they are generally terrestrial, some are aquatic—such as the beaver and water vole; some arboreal—such as the squirrel; some are cursorial, such as the hare; some fossorial, such as the mole-rat.

In the skull the zygomatic arch is invariably present, and the orbit is not separated by a bony rim from the temporal fossa. An extended diastema is universal, and intervenes between the incisors and premolars or molars. The palate is narrow in an antero-

posterior direction, and the mandible possesses a small coronoid process and a great development of the angle.

Sub-order	*Section I. Sciuromorpha*	(Squirrel-like)
(i) *Simplicidentata*	Family:	
	Anomaluridæ	
	Sciuridæ	(Squirrels)
	Castoridæ	(Beavers)
	Haplodontidæ	
	Section II. Myomorpha	(Mouse-like)
	Family:	
	Gliridæ	(Dormice)
	Muridæ	(Rats, mice)
	Bathyergidæ	(Cape-moles)
	Spalacidæ	(Bamboo-rats)
	Geomyidæ	(Pouched rats)
	Heteromyidæ	(Kangaroo rats)
	Dipodidæ	(Jerboas)
	Pedetidæ	
	Section III. Hystricomorpha	(Beaver-like)
	Family:	
	Octodontidæ	(Water-rat)
	Ctenodactylidæ	
	Caviidæ	(Capybaras, cavies)
	Dasyproctidæ	(Spotted cavies, agoutis)
	Dinomyidæ	
	Chinchillidæ	(Chinchillas)
	Cercolabidæ	(Tree porcupines)
	Hystricidæ	(Porcupines)

General Dental Characteristics.—NORMAL TYPE.—Rodents are generally diphyodont, but rats and mice are probably monophyodont.

The dental formula is very constant: I $\frac{1}{1}$ C $\frac{0}{0}$ Pm $\frac{1}{1}$ M $\frac{3}{3}$ $\times$ 2 = 20.

The incisors are scalpriform or chisel-shaped, grow from persistent pulps, and are curved, the curvature of the maxillary teeth being somewhat greater than that of the mandibular series. The anterior surfaces

only are covered with enamel, which is usually of a very complex pattern and at times highly pigmented. Canines are never present. The molars may be entirely rootless or rooted, their crowns tuberculated, bunodont, or lophodont. The enamel is tubular in the jerboas. The movements of the mandible are restricted to forward and backward direction. Hence the presence of the long diastema, which probably also serves as a cheek pouch for the storage of food, and at the same time allows the incisors to attain their usual enormous length.

ABERRANT TYPE.—In *Hydromys* (ὕδωρ—water; μῦς—mouse) there is a reduction in the number of the incisors and molars, and premolars are absent. The formula is: I $\frac{1}{1}$ C $\frac{0}{0}$ Pm $\frac{0}{0}$ M $\frac{2}{2}$ $\times$ 2 = 12.

Sub-order	*Family*	
(ii) *Duplicidentata*	*Leporidæ*	(Rabbits, hares)
	Lagomyidæ	(Pikas and calling hares)

These are distinguished from the former sub-orders and Families by the presence of two extra-maxillary incisors, placed behind the large curved ones.

The *hare* presents an unusually large number of teeth for a rodent, its formula being: I $\frac{2}{1}$ C $\frac{0}{0}$ Pm $\frac{3}{2}$ M $\frac{3}{3}$ $\times$ 2 = 28.

FIG. 300

The skull of a hare (*Lepus europæus*). $\times \frac{1}{3}$.

ORDER VIII. CREODONTA (Κρέας—flesh; ὀδούς—tooth)

Extinct carnivores

ORDER VII. CARNIVORA (*caro*—flesh; *vorare*—to eat)

This Order consists of small and large quadrupeds, of usually carnivorous habits. They may be terrestrial, arboreal, or aquatic. The teeth, generally, have sharp and cutting edges, the incisors are small and canines large. The toes are never less than four in number; the claws usually being long and sharp. Clavicles may exist in an incomplete form, or they may be entirely absent. The brain is well developed, and the cerebral hemispheres present numerous convolutions. The stomach is always simple, and the cecum, when present, small.

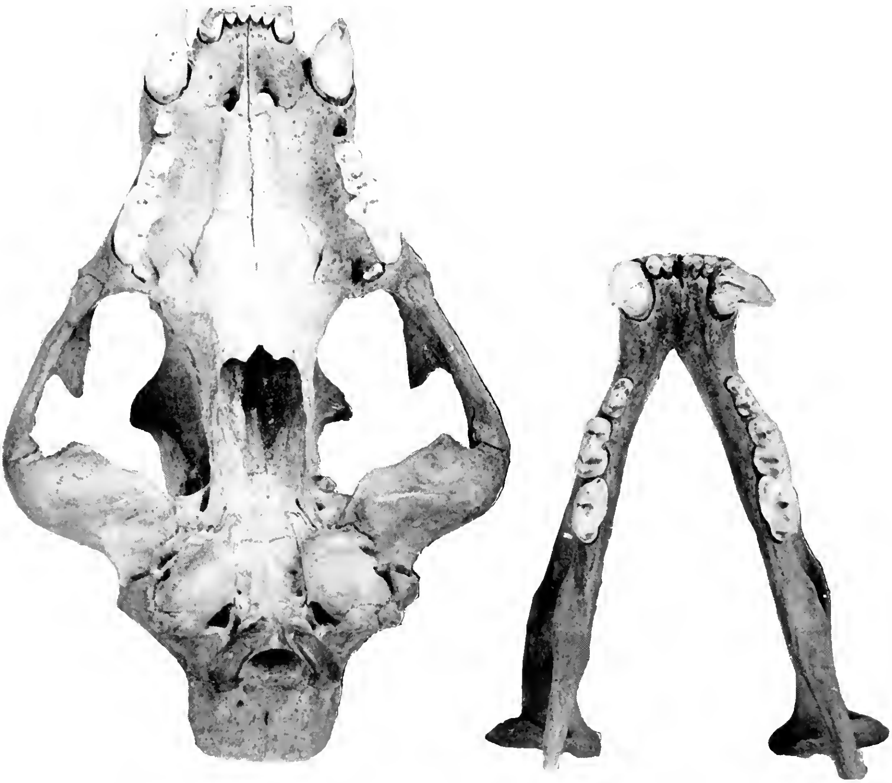
Sub-order	*Family*	
(i) *Fissipedia* (cleft-feet) (Terrestrial)	*Felidæ*	(Lions, tigers, cats, leopards)
	Machærodontidæ	
	Vivveridæ	(Civets)
	Hyænidæ	(Hyænas)
	Canidæ	(Dogs, foxes, wolves)
	Procyonidæ	(Raccoons)
	Mustelidæ	(Badgers)
	Ursidæ	(Bears)
(ii) *Pinnipedia* (fin-feet) (Aquatic)	*Otariidæ*	(Sea lions)
	Trichechidæ	(Walrus)
	Phocidæ	(True seals)

General Dental Characteristics.—NORMAL TYPES.—(*i*) *Fissipedia.* Somewhat small in size, the incisors are almost invariably six in number; the canines are large, strong, and always present. The last maxillary premolar (Pm^4 and ^4Pm) and the first permanent mandibular molar, (M_1 and $_1M$) are "carnassial" or "sectional" teeth, which are often much larger, and much longer, than the other premolars and molars, those in front of the "carnassials" being small and cone-shaped, those behind tuberculated, and with broad crowns. The simpler cheek teeth are frequently trituberculate, others multituberculate.

In the primitive type of carnivora the skull is larger than in the more specialized forms, such as the *Felidæ*. There is no soft palate.

The mandible has an elevated coronoid process, and the condyle, almost cylindrical, is elongated in its transverse diameter, and fits very closely into the glenoid cavity.

FIG. 301



Jaws of a lion (*Felis leo*). $\times \frac{1}{3}$. The jaws are placed side by side to show their relative proportions.

There are no typical carnivores in Madagascar or Australia. The dental formula in the *Felidæ* is: I $\frac{3}{3}$ C $\frac{1}{1}$ Pm $\frac{2}{2}$ or $\frac{3}{3}$ M $\frac{1}{1} \times 2 = 28$ or 32.

In this Family the blade of the maxillary carnassial is trilobed, and the mandibular molar has no internal cusp.

These are typically carnivorous. Lions may attain the age of seventy years, cats fifteen.

The extinct cats (*Machærodontidæ*; μάχαιρα—a sword or sabre) include the "Sabre-toothed Tigers," creatures who had enormous

maxillary canines, the possession of which probably caused the extinction of the species, inasmuch as these teeth were of such huge dimensions that they probably became, as Flower suggests, an inconvenience and hindrance to their owners. They could not be used as cutting instruments, and greatly interfered with the act of feeding.

The genera of *Civets* differ very considerably in their dental formulæ: the majority possess a greater number of teeth than the cats.

FIG. 302

The same—side aspect. $\times \frac{1}{3}$.

Hyænas are noted for the possession of an additional maxillary premolar. External and internal cingula are found, as has already been described.

An aberrant type of the *Hyænidæ* is the *Aard-wolf* of South Africa, where the molars and premolars are rudimentary and ill-developed.

Dogs, *Wolves*, etc., have the following formula:

$$\mathrm{I}\ \tfrac{3}{3}\ \mathrm{C}\ \tfrac{1}{1}\ \mathrm{Pm}\ \tfrac{4}{4}\ \mathrm{M}\ \tfrac{2 \text{ or } 3}{2 \text{ or } 3} \times 2 = 40 \text{ or } 44.$$

Dogs are typical mixed feeders, and have large carnassials, with a talon or tubercle on the mandibular corresponding tooth.[7 8 16]

An almost typical mammalian dentition is met with in the *Bears*, the difference being that there are only two maxillary molars. In adults second and third premolars are shed, thus forming the exception

to the rule, that when premolars are lost, it is from the anterior end of the series that the loss takes place. The carnassials are degenerated.

FIG. 303

Jaws of a typical civet (*Viverra civetta*). $\times \frac{4}{5}$. The jaws are placed side by side to show their relative proportions.

FIG. 304

Skull of a long-muzzled dog (*Canis familiaris*). $\times \frac{1}{2}$.

The brown bear eats roots, fruit, sometimes carrion, honey, and ants. The *Badger* (*Meles*) possesses thirty-eight teeth. The first

premolar is very small, and often early shed, the maxillary molar is a large quadrangular tooth, as broad as it is long, far surpassing the "carnassial" in size. The mandible is so firmly articulated to the glenoid cavity that it cannot be separated without fracture.

The American Raccoons are small carnivores, with short, broad, maxillary "carnassial" teeth and two pairs of molars in each jaw.

FIG. 305

Jaws of a sea otter (*Latax lutris*). $\times \frac{4}{5}$. The jaws are placed side by side to show their relative proportions.

ABERRANT TYPE.—The *Sea-otter* has a formula:

$$I\ \tfrac{3}{3}\ C\ \tfrac{1}{1}\ Pm\ \tfrac{3}{2}\ M\ \tfrac{1}{2} \times 2 = 32.$$

Here the jaws are short, and the teeth are large, the molars having flattened and rounded crowns. It eats crabs, sea-urchins, and, at times, small fish. The shells are crushed by means of the flat-topped molars, being held by its fore-paws.

(*ii*) *Pinnipedia*. The deciduous dentition is feeble and shed at an early period of growth:[9] there is a tendency to a homodont type in the pattern of the cheek teeth: there are no "carnassial" teeth: the number of incisors is reduced below the typical number.

The great majority are canine, and most feed on fish and crustaceæ.

Fig. 306

Skull of a brown bear (*Ursus arctus*). × $\frac{1}{3}$.

According to Mr. W. H. Elliott[6]—"The fighting between the old male eared-seals for possession of the cows is entirely done with the mouth. The opponents seize one another with their teeth, and then, shutting their jaws, nothing but the sheer strength of the one and the other tugging to escape can shake them loose, and that effort invariably leaves an ugly wound, the sharp canines tearing out deep gutters in the skin, and furrows in the blubber, or shredding the flippers into ribbon-strips. The bulls generally approach each other with comically averted heads, just as though they were ashamed of the rumpus which they are determined to precipitate. When they get near enough to reach one another, they enter upon the repetition of many feints or passes before either the one or the other takes the initiative by gripping. The heads are darted out and back as quick as a flash; their hoarse roaring and shrill piping whistle never ceases, while their fat bodies writhe and swell with exertion and rage; furious lights gleam in their eyes; their hair flies off into the air, and their blood streams down. All this combined makes a picture so fierce and so strange that, from

its unexpected position and its novelty, this is one of the most extraordinary brutal contests man can witness."

The *Walrus* presents a remarkable difference in its dentition from the seals. The maxillary canines are developed into enormously long tusks which are persistently growing (Tomes[17]). They project far beyond the lips and below the lower jaw. The molars have flattened crowns, and, with the premolars, are small, simple, and single-rooted. The tusks are used for raking out of the mud, certain shell-fish, on two species of which they live entirely.

The formula probably is: I $\frac{1}{0}$ C $\frac{1}{1}$ Pm $\frac{3}{3}$ $\times$ 2 = 18.

FIG. 307

Skull of an eared seal (*Otaria*). $\times \frac{1}{2}$.

The true *Seals* are best adapted for aquatic life. External ears are wanting. Every species has five pairs of cheek teeth, the number of incisors remaining variable. In the "grey" seal most of the cheek teeth are single-rooted; the typical seals have cheek teeth, which are small, and—excepting the first pair in each jaw—are implanted by double roots. The crowns carry accessory cusps.

The dentition of the *Monk-seal* is characterized by the presence of thirty-two teeth, the crowns of the cheek teeth being hollowed out on the internal aspects, where there is a strongly-marked basal ledge. The first cheek teeth are rudimentary.

ORDER VI. CETACEA (*cetus*—a whale)

The Cetaceans comprise whales, sperm-whales, porpoises, and dolphins. They have the following characteristics with other mammals: they are warm-blooded, possess lungs, bring forth their young alive, and feed them on milk. They, however, differ in the fact that they are admirably adapted for aquatic life.

The body is fish-like—there is no neck. The fore limbs are paddles, and exhibit no visible signs of being composed of arms, forearms, wrists, hands, and fingers.

Whales live in all seas, some being found in the large rivers of South America and Asia. Whales, according to an estimate of Cuvier's, may live more than one thousand years. A whale born about the time in British history when Alfred the Great was burning the shepherd's wife's cakes, would probably be alive at the present day.

The "spouting" of cetaceans is mainly the condensed vapour "breathed" through the nasal orifices which are situated on the top of the head.

The "*Right*" *whale* and the *Walrus* are fast disappearing off the face of the earth, on account of the fact that the spread of civilization tends, in the main, to exterminate certain forms of animal life, and therefore gives value to the oil, the ivory, and the whalebone of these mammals.

Cetacea[3] are "aquatic" mammals of fish-like form; tail expanded into horizontal flukes; a fatty dorsal "fin" present in most species; anterior limbs converted into fin-like paddles; posterior limbs only represented by skeletal rudiments. The skull has a greatly developed facial portion; supra-occipital bones meeting the frontal, but overgrowing or growing in between the parietals; bones surrounding the organs of hearing loosely attached to the skull. Coronoid process of mandible absent, or very feebly developed. Teeth, when present, few or numerous, always of simple conical form, with, at most, traces of additional cusps; if absent, their place taken by whalebone. Cervical vertebræ of short antero-posterior diameter, often more or less completely welded together into a single mass. Scapulæ peculiarly

flattened. Phalanges of digits always more numerous than in other animals. Clavicles absent. Stomach complex. Lungs simple. Diaphragm obliquely set, and very muscular. Brain much expanded transversely, and well convoluted. Mammæ two, inguinal in position. They are classified in three sub-orders:

Sub-order	*Family*	
(i) *Mystacoceti* (*Μύσταξάκος*, moustache, *cetus*—a whale) Whalebone whales	*Balænopteridæ*	(Rorquals)
	Balænidæ	(Right whales)
(ii) *Odontoceti* (Toothed whales)	*Physeteridæ*	(Sperm whales and beaked whales)
	Delphinidæ	(Dolphins, porpoises)
	Platanistidæ	
	Squalodontidæ	(Extinct)
(iii) *Archæoceti*	*Zeuglodontidæ*	(Extinct)

A generalized cetacean dentition is seen in the Dolphin. The teeth are homodont, conical, sharp, curved, and very numerous. The arrangement of their interdigitation is splendidly adapted for seizing slippery, living prey.

The *Sperm-whale* grows to sixty feet. It yields sperm oil in the blubber, spermaceti from a cavity in the skull, from which are made candles and ointments, and ambergris, which is a perfume issuing from the intestinal tract, and floating on the surface of the sea.

Its dental armament is peculiar, in that in the upper jaw there are a few curved teeth partly buried in the gum, and in the lower, the deciduous series, many in number, persist throughout its life.

In the *Beaked Whales*, there are functionless, rudimentary, maxillary teeth, and in the mandible, a pair, sometimes four, of thin, flat, strap-like bodies which, as they pass out of the mouth, are at first straight, but at their terminations, bent over towards one another.

ORDER V. SIRENIA (*Siren*—a mermaid)

These are "aquatic mammals with but few scattered hairs; hind-limbs absent, fore-limbs paddle-shaped, tail flattened, and either whale-like or rhomboidal to circular in form. Nostrils on upper surface of not specially elongated snout. Clavicles are absent. The scapula has the normal mammalian form, with a well-developed and roughly median spine. The bones of the arm and hand articulate together as in land animals; the phalanges show, at most, traces of increase in number above the normal. Pelvis represented by a vestige. Stomach complex, lungs simple and not lobulated. Diaphragm oblique and very muscular. Brain peculiar in form, and but slightly convoluted. Mammæ two, and pectoral in position."[3]

There is but one family *Manatidæ*. It includes the *Manatee* (*manus*—a hand, probably because it uses its front limbs somewhat in the manner of hands), which is found in West African waters and the rivers, and on the shores of Eastern America.

General Dental Characteristics.—It has a large number of molars, which goes on increasing indefinitely during the life of the animal. They undergo attrition on account of the character of the food, which is mainly algæ, with sand intermixed. As many as twenty molars have been found in half of each jaw, but only six or eight are present at one time, and they resemble somewhat the molars of the tapir (*q. v.*). In the front of the mouth horny plates exist, covering up four rudimentary incisors in each jaw.

The enamel rods run in a straight line; the dentine at the outer surface, according to Tomes,[17] is permeated with canals of large size—which may have presented, in ancestral forms, a kind of vaso-dentine.

The Dugong lives in the Indian ocean, being fonder of deep water than the Manatee. It is not fluviatile. The maxillæ are bent at an angle, and carry two tusk-like incisors on the prominent premaxillary bones. The tusks have enamel over their front and sides, like that of a rodent, and they grow from a persistent pulp. In the female, they do not grow from persistent pulps, and do not project beyond the jaw. Enamel ensheathes the whole surface of the teeth.

The sloping surface of each half of the mandible is covered with a horny plate, which encloses eight or ten rudimentary functionless teeth, which soon become shed, or absorbed, and the plates are covered with stiff bristles, and are the analogues of whalebone. Posterior to the plates, there are four or five degenerated molars. These are composed of vaso-dentine, having externally a thick layer of cementum.

Fig. 308

Skull of a young Dugong (*Halicore dugong*). × $\frac{1}{8}$. Two pairs of molars only are developed.

The *Rhytina* is a genus which has recently become extinct. It disappeared finally in 1768, because it could not defend itself when attacked, and because it knew of no method by which it could conceal itself from its great and powerful enemy—Man. Behring, the discoverer of Behring's Island, on which he was wrecked, was responsible for slaying the rhytina, for the purposes of food, and incidentally caused the complete extinction of this mammal.

ORDER IV. UNGULATA (*Unguis*—a nail, or *ungula*—a hoof)

This Order comprises those terrestrial mammals which possess hoofs rather than claws or nails, being chiefly vegetarian and exhibiting mainly a herbivorous type of dentition. The teeth are more or less bunodont, with a great tendency to a lophodont type. It is a most extensive Order, embracing such creatures, apparently very dissimilar in form, size, and build, as the hyrax (the Biblical coney), the elephant, the horse, the rhinoceros, the pig, the antelope, etc. The existing members of the Order are all characterized by having toes enclosed either in hoofs or supplied with flat, broad nails. The elephant possesses five toes, the pig four, the rhinoceros three, the camel two, the horse one, on each foot. In the carpus the scaphoid and lunar bones are separate; no clavicles exist: the mandibular condyle is elongated transversely. The typical number of cheek teeth is seven, but when reduced, the premolars have disappeared, leaving the constant number of three pairs of molars in each jaw. Their surfaces are roughened by infoldings of the enamel from their superior and lateral aspects, and the complex patterns make them admirable for grinding food-like roots, leaves, grass, etc.

The ungulates comprise the following:

Sub-order I. (*Condylarthra*), extinct
Sub-order II. (*Ambylypoda*), extinct
Sub-order III. (*Anaglopoda*), extinct
Sub-order IV. (*Typotheria*), extinct
Sub-order V. (*Toxodontia*), extinct
Sub-order VI. *Proboscidea*

Existing Families

Elephantidæ	
(*Dinotheriidæ*), extinct	(Elephants)
Procavia, or	Hyrax
Equidæ	(Horses)
Tapiridæ	(Tapirs)
Rhinocerotidæ	(Rhinoceroses)

Sub-order VII. *Hyracoidea*
Sub-order VIII. *Perissodactyla*
Sub-order IX. (*Litopterna*), extinct
Sub-order X. *Artiodactyla*

Group I. Suina

Family *Hippopotamidæ*
Suidæ (Pigs, etc.)

Group II. Ruminantia

Family *Tragulina* (Chevrotains)
Tylopoda (Camels, llamas)
Pecora (Deer, antelopes, oxen, giraffe, goats, sheep, etc.)

General and Dental Characteristics.—Proboscideans[3] are "large vegetable-eating animals, usually scantily covered with hair, and with the nostrils and upper lips drawn out into a long proboscis. Five digits on both limbs. . . . Skull with abundant air cavities in the roofing and other bones. The incisors are developed into long tusks, exist in the upper jaw alone, in the lower jaw alone (*Dinotherium giganteum*), or in both jaws. There are no canines. The molars are lophodont. The clavicle is absent. The femur has no third trochanter. The bones of the carpus are serially arranged and do not interlock. . . ."

The persistently growing tusks which provide the ivory of commerce, the trunk, and the structure of the molars are three great distinguishing characteristics of the elephant.

Elephants may live, under favourable circumstances, for three hundred years or more. It is said that when Alexander the Great conquered Porus, the King of Media, he captured a great elephant that had fought for the defeated ruler, named him Ajax, dedicated him to the sun, and placed upon him a metal band inscribed "Alexander, the son of Jupiter, dedicated Ajax to the Sun." The elephant was found, alive, three hundred and fifty years later.

The molar teeth of the modern elephant are so huge that the jaws cannot accommodate more than two, and a portion of a third, at one and the same time. These are gradually replaced by others, by means

of an oblique succession, to the number of three, and during its lifetime twenty-four molars alone are erupted.

Each molar is made up of a number of transverse ridges consisting of dentine, bounded by enamel, all united together by cementum. The number of the plates varies greatly. In the Indian elephant, while the first permanent molar has only four transverse plates, the greatest number in any tooth may be twenty-seven.

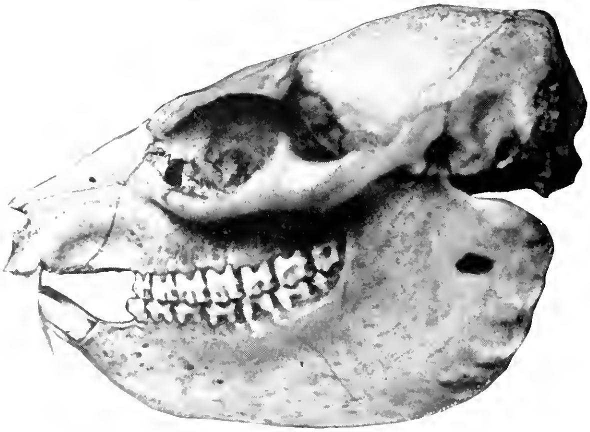
The Indian Elephant is found in India, Ceylon, and Malay. It is much used as a beast of burden, but is often very unreliable. Tusks are usually present in the male sex only. They may measure 8 feet in length, have a circumference of 17 inches, and weigh 90 or more pounds. Its food consists of grass, rice, and foliage. The ridges of the molars are narrow and set in a parallel fashion.

The African species has larger ears than its Indian congener. It can be tamed. Tusks occur in both sexes, but are relatively larger in the female than in the male. They are not sexual adornments only, but are used for uprooting tubers and roots for the purposes of food. For these operations the right incisor is used more frequently than the other, the result being that this tooth is somewhat the shorter and thinner of the two. Its food being of a softer character than that of the Indian species, the plates on the surface of the molars appear in lozenge-shaped ridges, of which perhaps only six or seven may be found in each.

The genus *Hyrax* consists of a group of small rodent-like mammals known as coneys. Their molars are much like those of the *Rhinoceros;* their incisors grow from persistent pulps. According to Woodward[20] the milk dentition is: I $\frac{3}{2}$ C $\frac{1}{1}$ Pm $\frac{4}{4} \times 2 = 30$ and the permanent dentition is: I $\frac{1}{2}$ C $\frac{1}{0}$ (persistent deciduous teeth) Pm $\frac{4}{4}$ M $\frac{3}{3} \times 2 = 36$. The incisors are prismatic, and the enamel is tubular.

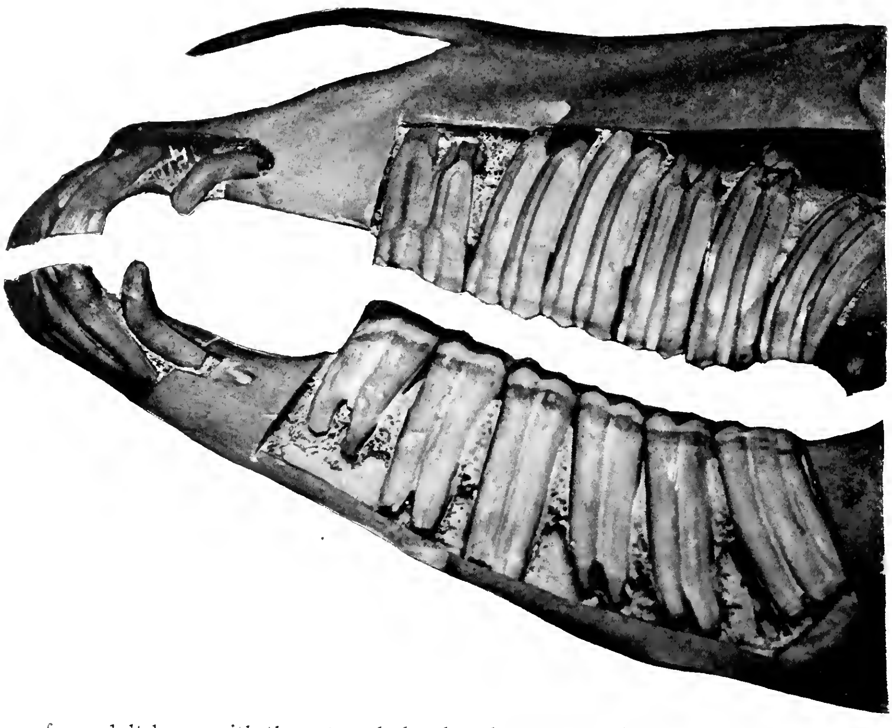
The *Perissodactyla* (Περισσὸς—excessive, or odd; δάκτυλος—toe) are odd-toed ungulates, and possess a toe which corresponds with the middle digit of the human hand or foot, and is larger than those on either side. The total number of toes in the fore foot never exceeds four. Those in the hind foot never exceed three. The tapirs of Malay and Tropical America come of a very primitive and ancient stock, and have a remarkable geographical distribution. The number of teeth

FIG. 309



Skull of a hyrax (*Hyrax capensis*). × $\frac{1}{1}$.

FIG. 310

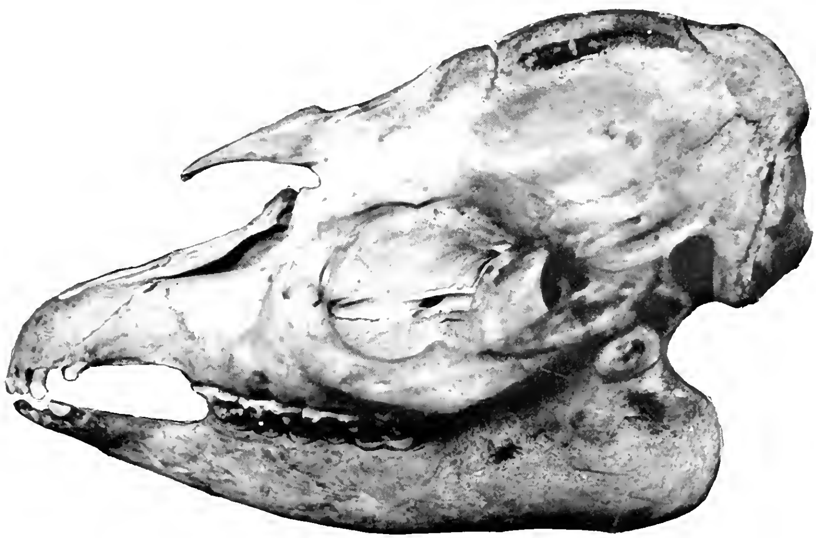


Jaws of an adult horse, with the external alveolar plates removed to show the shapes, sizes, positions, and roots of the teeth, and the cancellous nature of the bone of their sockets. × $\frac{2}{3}$. The fourth premolars are generally somewhat larger teeth than the molars. The first premolars had, as usual, been shed early.

is forty-two.[11] The cheek teeth are bunodont, the maxillary molars possess two conical tubercles, which are placed in an antero-posterior position. They are united by a ridge which forms the buccal wall, and, running slightly obliquely across the crown, are two transverse crests. Each mandibular molar has two transverse ridges.

The newly born Brazilian *Tapir* differs very considerably in colour from its parents, its grey coat being marked with stripes and spots which disappear as it gets older. These markings are particularly instructive, for they reveal the fact that young animals more closely

FIG. 311

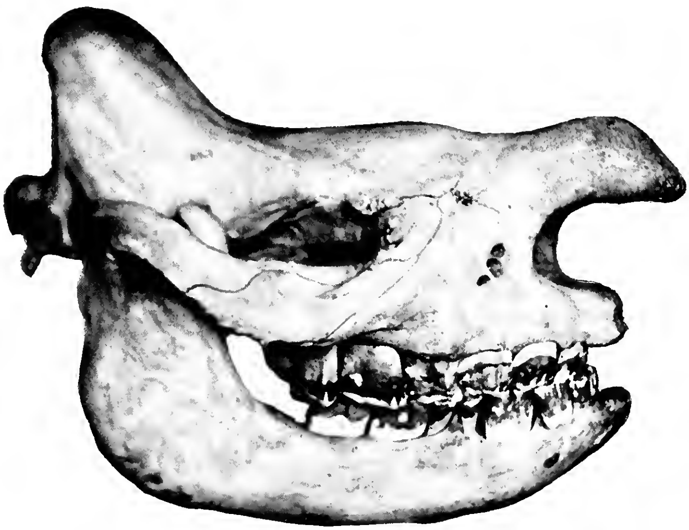


Skull of the tapir (*Tapirus indicus*). $\times \frac{1}{2}$.

resemble their remote ancestors than the present day adults of their genus. The tapir comes from the same common ancestry as the horse, and the stripes and spots of the young tapir are reminders of this fact, which has been over evolved in the stripes of the zebra, and the spots often seen in the coat of a well-groomed horse. While the latter has been modified into the form which is so familiar, and another line of descendants has evolved into the equally dissimilar rhinoceros, the original tapir form, as shown by fossil remains, has continued unaltered through many ages. Hence this grouping of the perissodactyles.

The *Horse* family presents evidences of descent from a four-toed ancestor (*Orohippus*—ὅρος—a limit; ἵππος—horse) and the three-toed *Protohippus*, by the occurrence of the so-called "splint bone," which corresponds to the metacarpals and metatarsals of the second and fourth digits of the typical five-toed foot. The premolars and molars consist of tall (hypsodont) quadrangular bodies, with the enamel thrown into a complex pattern of deep plications, the intervening flutings being filled with cementum.

FIG. 312



Skull of an African rhinoceros. × $\frac{1}{10}$. In this example there are three pairs of molars and three pairs of premolars only. The Indian species possesses a pair of incisors which are used for combative purposes.

The young horse has the typical mammalian dentition. The incisors have the summits of their coronal portions deeply involuted like the finger of a glove of which the tip has been pressed inwards. The age of the animal can be approximately computed by the depth, or otherwise (produced by attrition) of the cutting surface, including the cavity, the wearing down being occasioned by the constant biting of the teeth edge to edge. The canines occupy the centre of an extended interval (*diastema*) between the incisors and premolars; they are rudimentary organs in the mare. Both maxillary and mandibular

premolars number generally eight on each side of the jaw, though the anterior member of the series is frequently lost at an early age; they have as complicated a pattern as the molars, and are remarkable, in that they are usually as large, if not actually larger, than the last-named teeth themselves.

FIG. 313

A *B* *C*

Teeth of (*A*) tapir; (*B*) rhinoceros, and (*C*) horse; to show relative sizes of crowns.

The *Rhinoceros* is distinguished from the tapir and the horse by having, in modern species, forty-two teeth. The upper molars differ also morphologically, inasmuch as their buccal surfaces form continuous walls undivided into lobes. Their morsal surfaces consist, primarily, of two pairs of oblique transverse ridges, which are more irregular in outline than obtains in the tapir. The corresponding ridges in the mandibular series assume the form of crescents instead of simple transverse crests.

ARTIODACTYLA (*ἄρτιος*—even; *δάκτυλος*—toe)

General and Dental Characteristics.—The *Hippopotamus* is confined to Africa. It constitutes the most primitive and least specialized type of the existing members of this group. The cylindrical incisors are persistently growing. In the maxilla they curve in a downward direction; in the mandibles they project forwards. The canines also grow continuously, those in the upper jaw being directed downwards. The molars are tuberculated, possessing four tri-lobed cusps, each separated by a deep longitudinal and transverse groove. They undergo some attrition, as the hippopotamus feeds on aquatic plants with which

much sand is intermingled. At first, the wearing down of the surfaces produces the appearance of four trefoils; later a two four-lobed pattern obtains; and lastly, all original mould is lost, the edges being composed of enamel with a large central area of dentine.

Pigs, to which the former show general dental affinities, have the following dental formula: I $\frac{3}{3}$ C $\frac{1}{1}$ Pm $\frac{4}{4}$ M $\frac{3}{3}$ $\times$ 2 = 40.

Fig. 314

Skull of a wild boar (*Sus scrofa*). $\times \frac{1}{3}$.

Of the maxillary incisors the two median teeth are placed in the jaw in such a way that, widely divergent at their base, the cutting edges, which are not at all trenchant in character, become approximated very closely to one another; and the outermost teeth, separated from the others by a short gap, are usually smaller in size and general features. The straight mandibular incisors are procumbent, and have, in young specimens, on their superior surfaces, very marked longitudinal ridges of enamel.

In the male the canines are sexual teeth, being larger than in the female. Domestication has probably reduced their magnitude, because those of the wild boar are much greater than those of the ordinary familiar pig. If a young pig is deprived of the powers of generation, through excision of the testes, the huge development of the tusks is interrupted and arrested. The upper canine, throughout its length,

is curved into the form of a semi-circle, though the direction of its socket is horizontal with the body of the jaw. Thin bands of thickened enamel are found on its lower and external surfaces, to withstand the wear occasioned by the use of the lower canine. This is a prismatic

Fig. 315

Jaws of a wild boar (*Sus scrofa*) placed side by side to show their relative shapes, lengths, and widths. × $\frac{1}{3}$. The molars increase in size from before backwards, the third being a long, narrow composite tooth. *Cf.* Fig. 312.

tooth, less pronounced in form than the corresponding maxillary organ, and its posterior internal surface is devoid of a covering of enamel.

In the *Sus babirussa* the maxillary tusks become inclined upwards before they leave the body of the jaw, and appear as if they arose

from its dorsal surface. The older writers believed that, by means of these enormously curved teeth, the animal could, and did, sometimes, suspend itself from the branches of trees. (Beddard.)

The cheek teeth increase in size from before backwards. The first is a small wedge-shaped, bi-rooted tooth, the first premolar of some writers, but perhaps a deciduous molar;[10] the fourth premolar is brachyodont, bi-tuberculate, and quadruple rooted. The first molar possesses four cusps divided by a cruciform sulcus, the cingulum is elevated into a posterior transverse ridge; the cusps of the second molar present small accessory tubercles and the posterior transverse ridge is pronounced, being still more highly developed in the third member of the series, while the tooth itself is almost twice the length, in the mesiodistal diameter of its immediate neighbour.

The *Dicotylidæ*—the *Peccaries*—the small American swine, have the extremities of their maxillary tusks directed downwards in the ordinary way, the posterior edges being narrow and sharp. The total dental armament numbers thirty-eight members.

Selenodont teeth are found in the *Camels*, *Llamas*, *Oxen*, etc. All animals possessing these are ruminants, that is, they chew the "cud," an Anglo-Saxon derivative which is applied to the re-chewed food regurgitated into the mouth from the first stomach. In the camels, all premolars and molars are selenodont, and therefore non-tuberculated. The formula here is: $I\,\frac{1}{3}\ C\,\frac{1}{1}\ Pm\,\frac{3}{2}\ M\,\frac{3}{3} \times 2 = 34$.

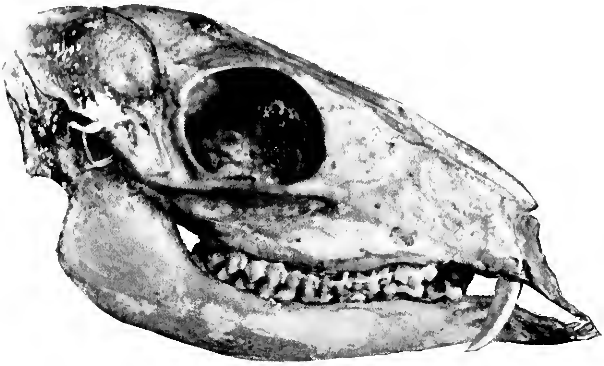
The males of the *Chevrotains*, hornless deerlets, or mouse-deer, have well-developed maxillary canines which are said to be used for suspensory purposes. The formula is: $I\,\frac{0}{3}\ C\,\frac{1}{1}\ Pm\,\frac{3}{3}\ M\,\frac{3}{3} \times 2 = 34$.

They differ from camels in the absence of maxillary incisors, and in the lower jaw the canines are approximated to the incisors. They form the oldest type of *Selenodontia*, and are oriental and West African in range. The tusks of the males of the species *Tragulus* must not be confused with those of the *Moschus moschiferus*—the musk-deer.

Cervidæ. The deer tribe is one of four families which constitute the *Pecora* or true ruminants. Like the camels and chevrotains they chew the "cud," and closely agree with the latter, in that the maxillary incisors are entirely absent, their place being occupied by a fibrous pad covered with thick oral epithelium. The lower canine assumes

an incisiform character, and is placed close to the distal surface of the third incisor.

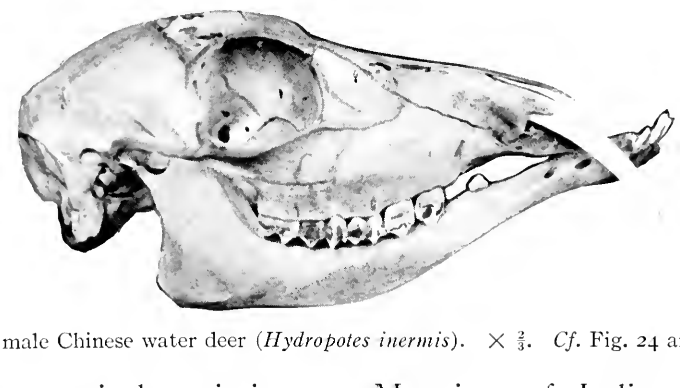
FIG. 316



Skull of a chevrotain (*Tragulus meminna*). × $\frac{2}{3}$. Both sexes are hornless, and both possess well-developed maxillary canines.

Deer are never found in Africa south of the Sahara, nor in Madagascar. Their heads are ornamented with antlers—branched deciduous appendages incorrectly termed "horns," which grow from the frontal bone.

FIG. 317



Skull of a male Chinese water deer (*Hydropotes inermis*). × $\frac{2}{3}$. *Cf.* Fig. 24 and Fig. 316.

The more typical varieties are Muntjacs of India, China, and Eastern Thibet, the male being distinguished by large maxillary canines; and closely allied are other small deer from the same localities, *viz.*, the genus *Elaphodus*, "tufted deer," the males of which have large upper canines. The genus *Cervus* includes red deer and fallow-deer, and is confined to the Old World except the magnificent Wapiti.

Rudimentary canines exist in the jaws of many deer, but it is clear that the common fallow-deer of the British parks, the roe-deer, and the Persian fallow-deer have none. The *Hydropotes inermis*, inhabiting the islands of the Yang-tse-kiang, is an aberrant antlerless member of the last family, and resembles the musk-deer in the remarkable length and strength of its maxillary canines.

Other members of the *Cervidæ* are the reindeer, and the elk or moose, the largest representative of all living deer, whose dental characteristics conform to the usual type.

Fig. 318

Skull of a camel (*Camelus dromedarius*). $\times \frac{1}{9}$.

It is thus obvious that maxillary canines are generally absent in the deer, and are present in the musk deer, the Muntjac, the goat-like Chinese water deer, and the tufted deer.

The *Giraffe* (Arabic *zaraf*—"one who walks quickly") is indigenous to Africa, its long neck consisting only of seven vertebræ, as in the dissimilar hippopotamus, serves as a watch-tower, like that of the ostrich, which lives under like conditions. There are no maxillary incisors or canines; the premolars are *brachyodont*, a characteristic feature in the mandible being the length of the diastema—between the incisors and canines. The gregarious *Pronghorn* of Eastern, Central, and North America is regarded as a distinct family, from the fact that

not only are the sheaths of the antlers branched, but that they are annually shed, and their place taken by new "velvet" which has been growing up beneath the old ones. The dentition requires no special description.

The largest group of the artio-dactyle ungulates is that of the hollow-horned ruminants or *Bovidæ*. The horns are unbranched, are composed of an underlying core of osseous material springing from the frontal bone, and are covered with a hollow horny sheath which is never shed. Hence the difference from antlers.

Some are possessed of maxillary canines. *Antelopes*, the least specialized group, have a hypsodont type of dentition. Broad, square, maxillary molars are found in the African duikerboks (*Cephalophus*); narrow maxillary molars in the African *Antelope*, the elegant *Gazelle*, the *Sheep*, etc. In the *Ox*, *Sable antelopes*, *Buffaloes*, and *Bisons* the maxillary molars are tall, broad, and quadrilateral, and on the lingual side, a narrow, but well-defined accessory column is added to the four large normal crescentic ones. In the *Kudus* the broad, square crown may be either hypsodont or brachyodont.

Sheep, *Goats*, *Chamois*, and *Musk-ox* are markedly hypsodont, the upper molars having only four crescentic columns.

ORDER III. GANODONTA (Wortman)
Extinct

ORDER II. EDENTATA (*E* or *ex*—without; *dentes*—teeth)

The Edentates are "terrestrial, partly subterranean, or arboreal creatures of quite small to gigantic size (some extinct genera) with frequently a covering of scales or bony scutes. Limbs clawed. Teeth either totally absent, or, if present, imperfect in structure, being without enamel, and not forming a complete series, incisors and canines, as a rule, being absent." (Beddard.)

The Order contains the *Sloths*, *Ant-bears*, *Armadillos*, *Manis*, and *Orycteropus* (Cape Ant-eater or Aard-vark).

The term applied to this Order is only partially correct, as many

members possess teeth; though enamel organs have probably existed in fœtal conditions.[1 13 17]

One genus, *Armadillo*, has functional milk teeth.

Sub-order I	*Family*	
Xenartha (Ξένος, unusual; ἄρθρον, joint)	*Myrmecophagidæ*	(Great ant-eaters)
	Bradypodidæ	(Sloths)
	Dasypodidæ	(Armadillos)
	Mylodontidæ, extinct	
	Megalomychidæ, extinct	
	Megatheriidæ, extinct	

Sub-order II	*Family*	
Nomarthra (Νόμιμος, usual; ἄρθρον, joint)	*Orycteropodidæ*	(Aard-varks)
	Group	
	Manidæ	(Pangolins)

General and Dental Characteristics.—The South American *Great Ant-eaters* are all anodontous.

The arboreal *Sloths* live in the forests of Tropical America. They possess no tails. Their movements are exceedingly slow, but they can conveniently escape the notice of their enemies by being difficult to distinguish from the twigs and leaves of the branches of the trees to which they cling. The hair is long and shaggy, and from the presence of adventitious green algæ gives the animal the appearance of a lichen-covered bough. Nature in the sloths is very imperfect, in spite of their excellent organization and habits with regard to their particular environments.

The teeth are almost cylindrical in section, rootless, and periodically growing, ten in the maxillæ and eight in the mandible, and are composed of vaso-dentine. Sloths are monophyodont and homodont.

The unique *Armadillos* frequently present a large number of teeth, sometimes as many as forty in each jaw. Generally speaking, however, the number is seven, eight, or nine in each half of the jaw, one being

implanted in the premaxillary bone. The teeth resemble those of the sloth.

In *Bradypus* the teeth are small, of equal size, and being placed opposite each other in the dental arches are permanently worn down flat. In *Cholœpus* the anterior tooth in each jaw is caniniform and twice as long as the others.

Fig. 319

Skull of a two-toed sloth (*Cholœpus*). × ⅘. The first pair of teeth in each jaw are longer and more tusk-like than the others. *Cf.* Fig. 58.

The *Aard-varks*, or *Earth pigs* of South Africa, are diplyodonts. According to Oldfield Thomas[15] there are seven deciduuos teeth in each maxilla—none in the premaxillæ; and in the mandible only four milk teeth in each half. The permanent series includes five premolars and molars in each half of each jaw, the latter being differentiated from the former in the presence of a median furrow which divides them into halves. They consist entirely of plicidentine; hence are similar histologically to those of *Myliobates.*

The *Pangolins* being ant-eaters, are, like the great ant-eaters, edentulous, though traces of a vestigial dentition can be found.[13, 16, 18] On occasion, they capture their food by erecting their scales and feigning death. Ants creep between these erected scales, which are then closed and the creatures carry their food to a stream, where they become submerged, and on liberating, the ants swim about and are speedily devoured by their temporary hosts.

ORDER I. MARSUPIALIA (*Marsupium*—a pouch)

The Marsupials differ from the preceding orders of *mammalia* chiefly from the point of view of the absence of placentæ. During intra-uterine life, the fœtal communicate directly with the maternal blood vessels by means of the placenta, an arrangement which ensures a more or less highly developed state at birth. In this group, however, there is no direct communication between the circulatory systems of parent and offspring; hence the imperfect state of development of the young at birth. They are called Implacental mammals, and structurally occupy a position in Nature between the *Prototheria* or Monotremes, and the more typical *Eutheria*, which they more closely resemble.

They may be defined as follows: "Terrestial, arboreal or burrowing (rarely aquatic) mammals, with furry integuments, palate generally somewhat imperfectly ossified; angle of lower jaw nearly always inflected. The clavicle is developed. Arising from the pubes are well-developed and ossified epipubic bones. . . . Teeth often exceed the typical Eutherian number of forty-four; molars generally four on each side of each jaw. As a rule but one tooth of the milk set functional, which is (according to many) the fourth premolar. . . ."

Many authorities regard the teeth as belonging to the deciduous dentition. Elsewhere it has been pointed out, however, that they probably really belong to the permanent series, and that the last premolar which gets shed is actually one of the permanent series which, through kinking of the tooth-band, has been extruded by another tooth beneath. The polyprotodonts only have a greater number of teeth than forty-four, and the feeble development of their marsupia indicates that they are the most primitive type of marsupial. Tubular enamel exists in the Wombat.[17]

Marsupials are now confined to the Neogæic realm, which comprises the Australian continent, Papua, Celebes, South and Central America. They are of very ancient lineage. In Mesozoic times they existed in North America and in Europe. In the former they persist to the present day, being represented by the opossums. In the latter they

became extinct during the Tertiary period. Diprotodonts exist in both America and Australia, a fact which may be explained by the hypothesis that there was formerly a land-connexion in the Antarctic hemisphere along which the Australian diprotodonts migrated into South America.

Sub-order I	*Family*
*Diprotodontia** (δύο—two; πρότερος—in front; ὀδούς—tooth)	A. *Macropodidæ* (Kangaroos, wallabies, rat-kangaroos, etc.)
	Sub-family 1. *Macropodidæ* (Kangaroos, wallabies)
	Sub-family 2. *Potoroinæ* (Rat-kangaroos)
	Sub-family 3. *Hypsiprymnodontidæ* (Musk kangaroos)
	B. *Phalangeridæ* (Phalangers)
	Sub-family 1. *Phalangerinæ* (Cuscus)
	Sub-family 2. *Phascolarctinæ* (Koalas)
	Sub-family 3. *Phascolomyinæ* (Wombats)
	Sub-family 4. *Tarsipedinæ* (Tarsipes)
	C. *Epanorthidæ*—*Cænolestes*
Sub-order II	*Family*
Polyprotodontia† (πολύς—many; πρότερος—in front; ὀδούς—tooth)	*Dasyuridæ* (Thylacines, Sarcophilus, "Native cats")
	Didelphydæ (Virginian opossums)
	Peramelidæ (Bandicoots)
	Notoryctidæ (Australian marsupial moles)

General Dental Characteristics.—The Diprotodonts are characterized by the number of the incisors of which there are never more than two in the lower and six in the upper jaw. The first are always large, having sharp cutting edges. The maxillary canines, if present, are small; in the mandible they are absent. The four pairs of molars possess broad quadrangular crowns, and have either four blunt,

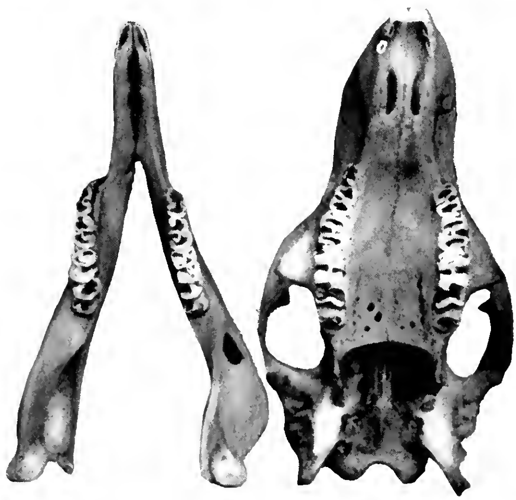
* This term refers to the mandibular incisors only.

† This term refers to the lower jaw only.

rounded tubercles or a pair of transverse ridges on their surfaces—a type of dentition admirably adapted to a vegetable dietary.

Kangaroos vary in size from that of a rabbit to that of a human being, and are specially noted from the possession of rooted teeth. The upper incisors are placed almost vertically. The lower project horizontally forwards. Owing to the laxity of the fibrous tissue which joins the two halves of the lower jaw, these latter are capable of undergoing movements like the working together of the blades of a pair of scissors.

FIG. 320



Jaws of a kangaroo (*Macropus rufus*). $\times \frac{5}{16}$. The jaws are placed side by side to show their relative proportions.

The formula is: $I\,\frac{3}{1}\ C\,\frac{0}{0}\ Pm\,\frac{1}{1}\ M\,\frac{4}{4} \times 2 = 28$.

Older animals possess: $I\,\frac{3}{1}\ C\,\frac{0}{0}\ Pm\,\frac{0}{0}\ M\,\frac{2}{2} \times 2 = 16$.

The upper incisors are rooted, the lower incisors are continuously growing.

In the *Hypsiprimnus* (Rat Kangaroo) of North Queensland the only premolar is exceedingly long and blade-like, with a narrow trenchant edge. It displaces two teeth, *viz.*, a tooth which is the one deciduous molar of some authors (dm^4) or the premolar of others, and also a premolar (Pm^2).

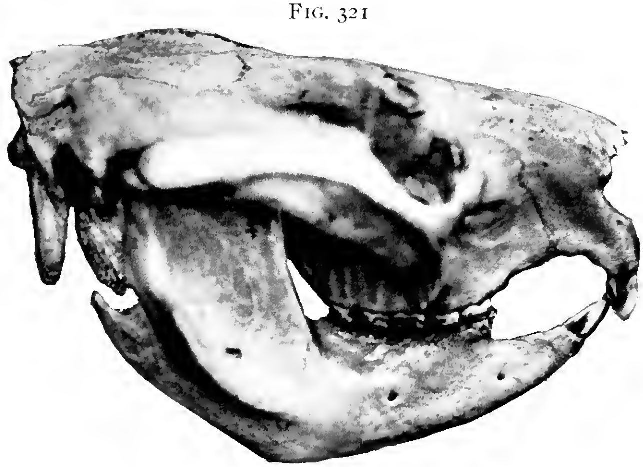
The teeth are variable in form and number in the *Phalangers*, the

canines are feeble, and a space divides the incisors from the molars. The number of teeth ranges from twenty-eight to forty, owing to the frequent presence of a number of small functionless anterior organs.

As a general rule, the formula is: $I\ \frac{3}{1}\ C\ \frac{0}{0}\ Pm\ \frac{2\text{ or }3}{2\text{ or }3}\ M\ \frac{4}{4} \times 2 = 32$ or 36.

They differ from kangaroos in the absence of the deep pocket-like pit, characteristic of that genus, on the outer side of the posterior portion of the mandible, and the lower incisors are not so freely movable on one another. All the phalangers are arboreal and of nocturnal habit. Most are provided with prehensile tails, few possess patagia, to enable them, like the flying lemur, to leap from tree to tree. The majority are vegetable feeders; some are, however, insectivorous and some carnivorous.

FIG. 321



Skull of a koala (*Phascolarctus cinereus*). $\times \frac{9}{10}$.

The solitary *Koala* of Eastern Australia somewhat resembles a small bear. It is tailless, has short, broad, dental arches, and large teeth. Its dentition is: $I\ \frac{3}{1}\ C\ \frac{1}{0}\ Pm\ \frac{1}{4}\ M\ \frac{4}{4} \times 2 = 36$.

Three species of Wombat, one of which is confined to Tasmania,[14] the others to Australia, South of the Tropic of Capricorn, are burrowing, rodent-like animals with the formula of: $I\ \frac{1}{1}\ C\ \frac{0}{0}\ Pm\ \frac{1}{1}\ M\ \frac{4}{4} \times \cancel{2} = 24$. ×2

This aberrant type differs from its congeners in that it is diphyodont.[13] Its dentition is rodent-like, all the teeth, including the molars, are persistently growing; cementum is found superficially, and the enamel is non-tubular.

Tarsipes, three inches in length, an insect and honey eater, has upper canines, fairly well-developed lower incisors, a single pair of maxillary premolars, and only three pairs of molars in each jaw. There is no inflexion of the angle of the mandible.

FIG. 322

Skull of the Dingo of Australia (*Canis dingo*). $\times \frac{1}{2}$.

Amongst the *Polyprotodonts*, *Dasyures* are carnivorous marsupials. They inhabit Australia, Tasmania, New Guinea, and many adjacent islands. There are eight incisors in the upper and six in the lower jaw. The molars have multicuspidate crowns.[15]

The *Thylacine*, or Tasmanian wolf, a dog-like creature, has the following formula: $I\,\frac{4}{3}\ C\,\frac{1}{1}\ Pm\,\frac{3}{3}\ M\,\frac{4}{4} \times 2 = 46$.

Sarcophilus differs in the fact that two pairs of premolars only are present in each jaw. The maxillary molars (except the fourth) are short, wide, triangular, and strong. Dasyures have teeth which are numerically similar to *Sarcophilus*, but they are not so well developed.

Opossums are distinguished from the last Family by having eight lower and ten upper incisors—fifty teeth in all.[9]

The dental formulæ of the Bandicoot is: $I\,\frac{5}{3}\ C\,\frac{1}{1}\ Pm\,\frac{3}{3}\ M\,\frac{4}{4} \times 2 = 48$.

The incisors are relatively small in size; the canines are tusk-like; the molars are multituberculate and very sharp.[19]

An aberrant type is seen in *Myrmecobius*, or banded ant-eater, which is very remarkable in its numerical variations of the teeth, of which the following is the formula: $I\,\frac{4}{3}\ C\,\frac{1}{1}\ Pm\,\frac{3}{3}\ M\,\frac{6}{6} \times 2 = 54$.

The molars are separated from one another by intervals; the inner cusps of the lower teeth being larger than the outer ones. Four pairs of mandibular incisors may, at times, be developed.

FIG. 323

Skull of an opossum (*Didelphys virginiana*). $\times \frac{2}{5}$.

FIG. 324

Skull of a bandicoot (*Perameles*). $\times \frac{3}{5}$.

The marsupial mole (*Notoryctes typhlops*) lives by burrowing in the sand of the deserts of Australia in search of insect food. This admixture of sand with the soft-bodied insects produces much attrition of the teeth. The animal is of a pale golden-red colour, and must be distinguished from *Chryschloris*, or Golden Mole. It measures in vertex-breach diameter about five inches. The maxillary molars have triangular crowns and carry three cusps only.

SUB-CLASS I. PROTOTHERIA

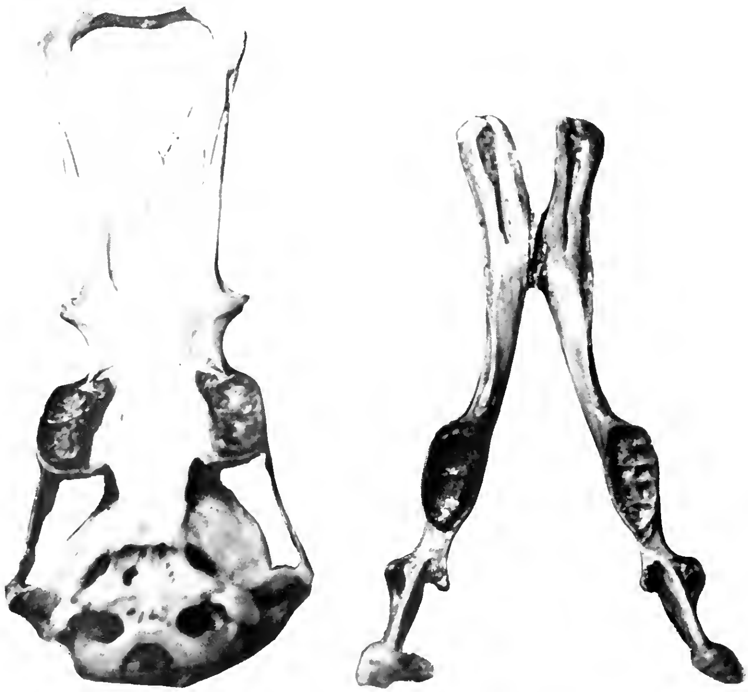
Contrary to the initiation of Professor Huxley, modern zoölogists divide Mammals into two primary classifications, *viz.:* (A) Prototheria and (B) Eutheria.

The preceding pages have dealt with the main features of the latter; it now remains briefly to describe the dental features of those creatures which stand at the base of the Mammalian series, and are the lowest in the scale of animals.

The order *Monotremata* (Μόνος—single; τρῆμα—aperture) include the *Ornithorhynchus* (Duck-billed platypus) and *Echidna.*

They may be defined as "*Mammalia* with no teats but with a temporary pouch in which the young are hatched, or to which they are transferred after hatching, and into which open the ducts of the mammary glands. . . . Mammary glands of the sudoriparous and not the sebaceous type of epidermic gland. Oviparous, with a large-yolked and meroblastic ovum, enclosed within a follicle of two rows of cells."[3]

Fig. 325



Jaws of a duck-billed platypus (*Ornithorhynchus.*) × $\frac{2}{3}$. The jaws are placed side by side to show their relative proportions.

The most salient feature of the group is that the "eggs are large-yolked and develop, so far as regards their early stages, therefore, after the fashion of the egg of a reptile."

There are some existing Families of these archaic creatures, (*i*) the *Echidnidæ*, and (*ii*) the *Ornithorhynchidæ*.

The *Echidna*, or Australian ant-eater, is edentulous and possesses no corneous substitutes for teeth.

The *Ornithorhynchus* is remarkable from its curious duck-like bill or "beak," which is covered with a fine skin in which many sensitive tactile nerve organs are situated.

Prior to 1888 it was believed to be toothless. Then, however, Poulton[12] discovered the presence of tooth germs in embryos. Oldfield Thomas[15] has clearly shown that eight or ten calcified molars exist; and he believes that they persist during a considerable part of the life of the animal, *i. e.*, about eight or nine months, during which time it is about half-grown,* and become shed after undergoing attrition by

FIG. 326

Skull of an echidna, or spring ant-eater. × 1/3.

food and sand, their places being taken by horny plates, which are developed from the oral epithelium growing around and beneath the calcified teeth. It is probably this mode of development of the corneous structures which determines the loss of the molars. If the superior surfaces of the former be examined it will be seen that they are grooved and hollowed for the implantation of the molars of which they form the remains by the original alveolar sockets.

The horny plates are four in number in each jaw; there are twelve teeth, eight large and four very diminutive. The maxillary series have broad crowns with two long lingual cusps and small accessory cusps along the border. A reverse anatomical condition obtains in the mandibular teeth. All have short roots. In structure the enamel is of a simple character and the dentine is supplied with an abundance

* In a private letter written in the spring of 1912, Mr. Brooke Nicholls, of Melbourne, tells the author that it is his conviction that these calcified teeth are not to be found after the third month.

of interglobular spaces, probably affording evidences of its origin from an earlier and completer form.

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GLOSSARY

Acrodont—*ἄκρον*, the summit—teeth placed on the top of the jaw, as in sphenodon and eel.

Aglypha—*α*, negative—*γλυφίς*—a notch or groove.

Alveolus—*alveus*—a hollow vessel (diminutive form of).

Basion—*basis*—the base.

Bilophodont—*bis*, twice; *λόφος*—a ridge—as in the *Tapir*.

Brachyodont—*βραχύς*—short.

Brachycephalic—*βραχύς*—short, *κεφαλή*—head; skulls of which the breadth is at least four-fifths of the length.

Bunodont—*βουνός*—a mound.

Caniniform—canine-like.

Cervical—*cervis*—a neck.

Chætodont—*χαίτη*—a mane.

Cingulum—*cingulum*—a girdle.

Coronal—*corona*—a crown.

Cursorial—*cursus*—running.

Deciduous—*deciduus*—falling off, or shedding.

Diastema—*διάστημα*—an interval.

Diphyodont—*δίς*—double or two; *φυλή*—a company or series.

Diprotodont—*δίς*—two; *πρῶτος*—front.

Distal—distant.

Dolichocephalic—*δολιχὸς*—long; *κεφαλή*—head; longheaded skulls.

Dents en brosses—teeth collectively like brushes.

Dents en cardes—teeth collectively like combs, whose antero-posterior diameter exceeds the lateral diameter.

Dents en velours—teeth collectively like velvet.

Edentata—*e*, negative; *dens*, *dentis*, a tooth—edentulous.

Entoconid—*ἐντός*—within, inside; *κῶνος*—a cone.

Ethnic—*ἔθνος*—a nation.

Eutheria—*εὖ*—ordinary; *θήρ*—a wild beast.

Fossorial—*fodio*, *fossum*, I dig—digging or burrowing.

Gomphosis—*γόμφος*—a nail.

Gonian—*γωνία*—an angle.

Gymnodont—*γυμνός*—naked or bare, as in the *Diodon*.

Haplodont—*ἁπλόος*—simple, as in the dolphin.

Heterodont—*ἕτερος*—different, as in Man, pig, etc.

Homoodont—ὁμός—alike, as in the dolphin, sloth, armadillo.
Hypocone—ὑπό—beneath or under; κῶνος—a cone.
Hypsodont—ὕψι—high, as in the horse, elephant.
Lophodont—λόφος—a ridge, as in the *Tapir*.
Macrodont—μακρός—large.
Megadont—μέγα—very much.
Mesial—μέσος—middle.
Mesodont—μέσος—middle.
Mesognathous—μέσος—middle; γνάθος—jaw.
Metacone—μετά—behind, κῶνος, a cone.
Microdont—μικρός—small.
Monophyodont—μόνος—one; φυλή—a series or company.
Morsal—*morsus*—a bite.
Multitubercular—*multus*—many, *tuberculum*, diminutive of tuber, a knob or cusp.
Occlude—*occludere*—to close, to shut up.
Odontogeny—ὀδούς—a tooth; γεννάω—to produce.
Opisthoglypha—ὄπισθεν, behind; γλυφίς—a notch or groove.
Orthognathous—ὀρθός—usual; γνάθος—mouth or jaw.
Paracone—παρά—in front of; κῶνος—a cone.
Patagium—a parachute.
Pectinate—*pecten*—a comb.
Pleurodont—πλευρά—the side; as in *Varanus*.
Polyphyodont—πολύς—many; φυλή—series.
Prognathism—πρό—forward; γνάθος—jaw.
Prosthion—πρόσθεν—in front.
Proteroglypha—πρότερος—in front; γλυφίς—a notch or groove.
Protocone—πρῶτος—first; κῶνος—a cone.
Prototheria—πρῶτος—first; θήρ—a wild beast.
Ptychodont—πτύξ—a fold, as in the molar of the rabbit.
Quadritubercular—*quatuor*—four; *tuber*—a knob.
Quinquetubercular—*quinque*, five; *tuber*—a knob.
Radulæ—*rado, radere*—to scrape.
Scalpriform—*scalprum*—a chisel, as in the rodents.
Selenodont—σελήνη (the Moon)—crescentic, as in the sheep or camel.
Teratoma—τέρας—a monster.
Thecodont—θήκη—a sheath, as in the crocodile.
Triconodont—*tres, tria*—three; κῶνος—a cone.
Tritubercular—*tres, tria*—three; *tuber*—a knob.

APPENDIX

NOTE A

A Case of Hereditary Absence of the Crowns of the Teeth

The following extremely rare hereditary dental abnormality, passing through six generations, has been referred to in Chapter II.

A. H., aged 21 years (February, 1910), is a member of a family which presents an extraordinary condition of the teeth.

The Family history is normal. The father, aged 59 years, a cottager; the mother is aged 57 years. She is opharmotic—*i. e.*, has an open bite—and is edentulous, except for the first right maxillary incisor, which, however, is loose. It has no crown. The root is black, shaped on its surface similarly to those of her children. She is hypermetropic.

All the members of the family are somewhat stunted with regard to their height. The hair is plentiful, the nails normal, the skin healthy and fine, the nervous system probably normal, though it would seem that the youngest son and the younger daughter are inclined to be mentally defective. A Hampshire family, living in a rural district on sandy soil, 370 feet above the sea level, where the climate is dry and the water "soft," it consists of parents, two daughters, and five sons, of whom three of the latter are married. Brief histories are as follow:

(1) Henry, aged 38 years, living with wife and son (2) at an elevation of 480 feet above sea level. Climate damp, water "soft." All the twenty anterior teeth are practically on the same plane as the surface of the gum. The maxillary third molars have ill-developed crowns; the right mandibular third molar has a natural crown with deep fissures. The first right mandibular molar is carious. He has had four maxillary and the left first mandibular molar removed on account of loosening, not "toothache."

(2) Henry, junior, son of (1), aged 10½ years, was breast fed. The tonsils were removed at the age of three years. There were no infantile diseases, nor any facial deformity. He is prosharmotic—*i. e.*, has an edge-to-edge bite. The deciduous teeth became loose and were shed. Teeth present: *Maxilla*—all incisors, the right canine erupting, the first molars in place, but having no crowns. The first right

premolar has a fairly-well shaped crown. *Mandible*—the incisors have flattened crowns, the deciduous canines are still present, the other teeth have deficient crowns.

Fig. 327

Plaster casts of mouth of a woman, aged twenty-two years. $\times \frac{9}{10}$. The patient was the member of a family who exhibited for six successive generations a tendency for failure of development of the crowns of the permanent teeth. See the accompanying text. Three maxillary molars had been extracted for the relief of bi-antral disease. The maxillary third molars and the right mandibular third molar have not yet erupted. At *x* an unerupted horizontally placed second premolar. The third molars in this patient and in a brother and sister possessed fairly well-developed crowns.

Fig. 328

Plaster casts of mouth of woman, aged thirty-six years. $\times \frac{9}{10}$. Sister of the patient of the preceding figure. The second right maxillary molar and the second left mandibular premolar and first molar have been extracted as a consequence of dental caries. The right mandibular third molar is not yet erupted.

(3) Rose, aged 36 years. All the teeth are lacking in well-developed crowns, except the left mandibular third molar. Appearances similar to those of the

FIG. 329

Plaster casts of mouth of a man, aged thirty-eight years. $\times \frac{9}{10}$. Father of the patient of the succeeding figure. The mandibular first left molar and the maxillary first and second molars on both sides have been extracted as a consequence of disease. The mandibular right first and second molars are carious.

FIG. 330

Plaster casts of mouth of a boy, aged ten and a half years. Son of the patient of the preceding figure. $\times \frac{9}{10}$. The maxillary right premolar is probably the first.

patient Annie. She is opharmotic, and caries is present in places. She has never had odontalgia. She is hypermetropic, and wears spectacles.

(4) Archibald, aged 19 years, quick and intelligent, has the appearance of being edentulous, having an epharmotic bite. Teeth are all levelled with the surface of the gum.

Fig. 331

Plaster casts of mouth of a boy, aged nineteen years. $\times \frac{9}{10}$. Brother of the patient of the succeeding figure. The right mandibular first molar and the left second premolar and first molar had been extracted as a consequence of dental caries.

Fig. 332

Plaster casts of mouth of boy, aged fifteen and a half years. $\times \frac{9}{10}$. The maxillary second left premolar has not erupted. The right first molar has been extracted.

(5) Ronald, aged $15\frac{1}{2}$ years, probably mentally deficient. All the teeth have their visible portions level with the surface of the gum, except the right maxillary second premolar, whose crown is cusped and fissured. He is opharmotic, the alveolar margins being 8 mm. apart at the "incisive spot."

(6) Sidney, aged 30 years. No notes at present.

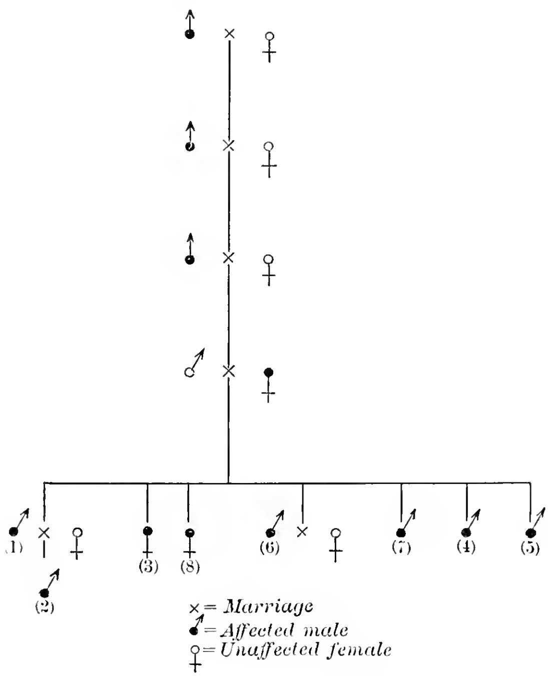
(7) Another brother living in America. No notes.

(8) The patient, Annie, aged 21 years, had been breast fed, had had measles and bronchitis. She is opharmotic. *Dental History:* There are ten maxillary and

fourteen mandibular roots present. The well-formed left mandibular third molar has a crown. The roots have polished hard brown surfaces; no pulp canals visible, but a slight depression occurs here and there. There are no traces of dental caries nor any deciduous roots remaining. An *x*-ray photograph showed an unerupted right maxillary second molar lying horizontally in the jaw, with its crown pressing on the root of the first premolar. She had been treated for bilateral antral disease. She complained (December 31, 1909) of a vague pain in the first premolar. As it was functionless, and as the crown of the second premolar was touching it, it was extracted and a section made. This showed no enamel, and appearances in the coronal dentine as if there never had been any enamel formed. On May 28, 1910, the unerupted premolar was extracted because it appeared to be keeping up the antral disease. This tooth possessed Nasmyth's membrane, but had no capsule. The removal of the tooth was followed by cessation of antral pains and symptoms of disease.

The above description does not at all pretend to be complete. The patients are being watched, and the cases are being still further investigated with a view to further and fuller publication.

GENEALOGICAL TREE

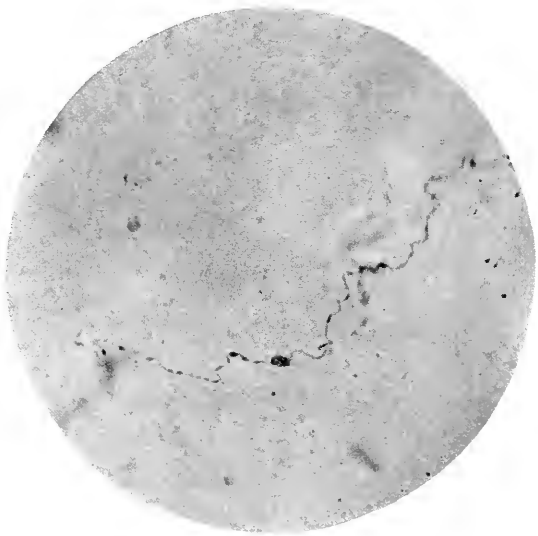


NOTE B

The Nervous System of the Dental Pulp

In view of the recent observations of Mr. Howard Mummery, on whose authority nerve fibrils enter the dentinal tubules, the author desires to record the fact that he has been able to stain the non-medullated fibres in the pulp by using several processes, notably those of Freund and Dogiel, and the intra-vitam methylene-blue methods.

Fig. 333

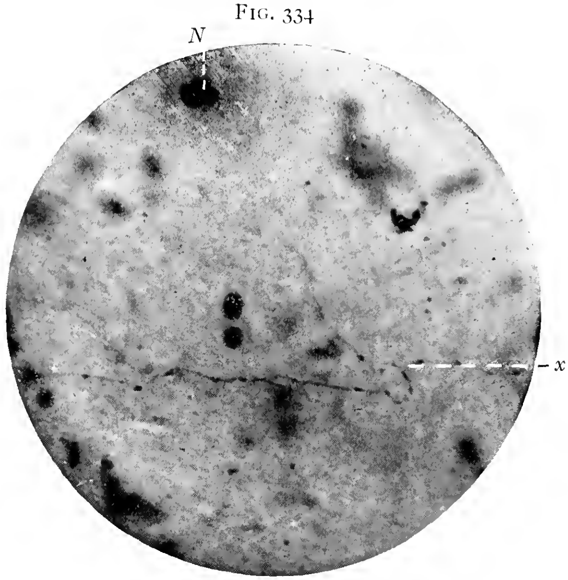


A non-medullated nerve fibre in the dental pulp of man. $\times \frac{750}{1}$. Photomicrograph by Mr. Douglas Gabell.

It is easy to demonstrate the *medullated nerve fibres*. Osmic acid shows them. They may be obtained practically unchanged by removing a permanent misplaced canine from the mouth of a child of 8 or 10 years (the apex being unclosed) with warm forceps, rapidly wiping off the blood, and placing at once in a warmed tube containing a 2 per cent. solution of methylene blue in physiological salt solution, kept at a temperature of 37° Centigrade for 30 minutes. After breaking in a vice, the pulp is removed and a scraping from the surface of the dentine is mounted in picro-glycerine. The *non-medullated nerves* may be rendered apparent by obtaining a young, freshly extracted human tooth—a canine for choice, carefully crushing it in the jaws of a vice, removing the pulp with a needle point, laying it on a slide,

and moistening it with a $\frac{1}{16}$ per cent. solution of methylene blue in physiological salt solution. In four hours the non-medullated nerve fibres will be stained. The process must be watched, as overstaining is easy. The preparation can then be mounted in picro-glycerine.

Fig. 334



Same as the preceding. $\times \frac{750}{1}$. At *x* the fibre branches into two divisions. *N*, nuclei of cells of the pulp. Photomicrograph by Mr. Douglas Gabell.

NOTE C

Oral Electricity

Electric cells are frequently formed in the mouth, metallic poles being present and an electrolyte intervening. The greater the electro-positive or electro-negative the metal the greater the electro-motive force. In the electrolytic scale, gold is nearly the most electro-negative of all metals placed in the mouth, while aluminium is the most electro-positive. If, therefore, two metals of different electro-motive force come into contact or almost into contact, and the saliva is ionized to such an extent as to be efficiently electrolytic, the cathions, or $-$ions, will move towards the $+$pole or more electro-positive side, while the anions, or $+$ions, will move towards the $-$pole, and a certain amount of electricity will be evolved.

This action may be carried to a greater degree than is usual in the mouth.

Clinically this force becomes more manifested, at times, under certain conditions, in a disastrous manner. Thus a 16-carat gold band which is used for supporting a denture, if attached to a molar tooth, for instance, which contains a large amalgam filling, may in these cases become so electrically affected as to break, on account of the molecular changes set up by the current, and the filling similarly to become disintegrated and ultimately become loosened.

Mere contact of a metal with enamel or dentine is not appreciated by the pulp. It is when two dissimilar metals are brought into contact, separated only by a thin film of saliva, which acts as the electrolyte, and the circuit is completed, that voltaic currents are set up—as for instance when the metal ring of a small mirror touches the surface of a gold or an amalgam filling. This, of course, constantly takes place during operations, and is as a rule unnoticed by the patient, on account of its extremely light character; but, at times, the pulp, stimulated by the electrical action, responds by a sudden spasm of acute neuralgic pain.

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